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OCCULTING MATTER IN SPACE.

By ELLIOTT SMITH.

In connection with the problems which deal with the observational evidence of the limiting distance at which stars may be observed from the earth it is logical to raise the question as to how much of the light which they radiate in our direction is intercepted by non-luminous matter in space. It is important, also, in this connection, to know to what occultations, if any, those stars are subject whose relative distances from the earth are determined by a comparison of their apparent magnitudes. For if the more distant stars are subject to greater occultations the numerical values derived for their distances will be greater than it should be. Were these distances then taken to represent the outlying limits of our observable stellar system the diameter thus derived for it would be too great.

The planets and satellites are familiar examples of non-luminous bodies which at times cut off our view of luminous celestial bodies, more distant, but of similar alignment. Meteors are other well known non-luminous bodies whose occulting properties should be taken into consideration for there is the possibility that the occulting matter of space may be made up of units of somewhat similar form, density and composition. Comets, also, should be considered in this connection because of their apparently close relation to meteors.

It is evident that planets, satellites and asteroids had intimately related origins within the solar system. Comets, until recently, were supposed to be of interstellar origin. This has been called into question on the grounds that the most reliable orbits indicate that comets are moving in elliptic orbits when they make their first appearance in the solar system.

There is the possibility, however, that a comet, moving with parabolic velocity toward the sun through space, may have encountered enough cometary and meteoric matter moving in other directions to decrease its velocity to that corresponding to motion in an elliptic orbit before it arrived in the gravitational field of the solar system. We have observational evidence of the encounter of comets' tails with meteoric

* Contribution to a Symposium on "The Infinity of the Physical Universe," Section D, A. A. A. S., Cincinnati, Dec. 28, 1923.

matter and we may presume that the greatly extended head of a comet undergoes many similar encounters beyond our field of view with a corresponding diminution in its velocity. That comets enter the solar system in elliptic orbits need not be accepted, therefore, as positive proof that they are not of interstellar origin.

Another line of evidence which indicates that comets are of interstellar origin is the comparatively brief time in which they perform their physical evolution, changing, as we infer, from light emitting bodies to non-luminous. The age of the earth is reckoned in millions of years. From this we conclude that the matter composing the sun and planets has been assembled into its present units and that they have been describing similar orbits for many millions of years. If comets were contemporaneous in time with the planets, even though moving in greatly elongated orbits, they must have ceased to be light emitting bodies long before the present epoch. We conclude from this that those now observed are comparatively recent acquisitions to the solar system.

There are valid reasons for supposing that the original solar nebula was spiral in form. If this is a correct supposition the plane of the ecliptic probably coincides with the central plane of the original spiral. If there were outlying units of the original nebula so distant that they did not share in the development which resulted in the formation of the planets because of the low gravitative attraction of the sun upon them, they, nevertheless, would be in the central plane of the spiral. Eventually drawn toward the sun by the force of gravitation they would move in elongated elliptic orbits whose planes would coincide very nearly with the plane of the ecliptic. The fact that the inclinations of the planes of their orbits have no definite relation to the plane of the ecliptic may be accepted as an indication that they are not units of the original solar nebula.

There is the possibility that meteors and comets may have been launched into space through the eruptive activities of the larger bodies of the solar system. If this were the case, however, we might expect to find a relation among their orbits which would suggest such an origin.

Whether their origin be solar or interstellar the fact that their orbits show, in general, no definite relation, one to the other nor to the plane of the ecliptic, indicates that their distribution about the sun is spherical. That the sun is surrounded by a spherical shell, many astronomical units in diameter, in which there is a distribution of meteoric bodies which have the property of cutting off the light which the sun would otherwise radiate into space, seems to me to be of significance in its relation to occulting matter beyond our solar system. The stars are suns which differ from each other because of their varying physical conditions. The spherical shell of meteoric bodies, corresponding to that which surrounds the solar system, might be of such density in a

distant stellar system as to decrease effectively the light emanating from it.

Observed meteors vary in mass from a few pounds to several thousand and, distributed in this form, they would cut off a percentage of the light without producing the change in its quality which we would expect it to undergo if it passed through gases. A spectroscopic analysis would give little or no evidence of the occultations suffered.

When we come to consider occulting matter in connection with distant celestial objects it is natural to turn first to Barnard's photographs of the Milky Way and of other regions of the sky. It was not recognized until recent years that non-luminous matter existed in the sky in any conspicuous quantity. In writing of the dark configurations on his photographs of the Milky Way as late as 1905[1] Professor Barnard spoke of them as vacancies. He says: "....their remarkable appearance as shown on Milky Way photographs has become decidedly fascinating." And again: "....these vacant regions are not dependents of the Milky Way entirely, for we find them also in nebulae and in or connected with clusters. The rifts of Lord Rosse in M 13 (the great cluster of Hercules) are not such striking features with powerful telescopes as we have been led to believe for they are filled with a luminosity which takes away their blackness when seen in a large telescope and I do not believe they penetrate very deeply into the cluster, while others—and perhaps more remarkable vacancies, rifts and lanes—are found in the less dense outlying regions of this cluster and indeed in many of the other clusters—notably in Messier 5 Librae."

In 1919 Professor Barnard published a "Catalogue of 182 Dark Markings of the Sky."[2] The nomenclature of this title is significant of the conclusions drawn from his careful study of these dark places, between the dates of the two publications cited. In the introduction to his catalogue he says: "It would be unwise to assume that all dark places shown on photographs of the sky are due to intervening opaque masses between us and the stars. In a considerable number of cases no other conclusion seems possible...." He then cites a number of conclusive examples and, referring to the Taurus region, writes: "....a nebula, only partly luminous, seems to fit in a hole in the sky. Even a casual inspection shows that this nebula can be fully seen over the entire spot where all the stars are blotted out sharply and that the absence of stars is due to the obscuring presence of the nebula. This object is really the key to the explanation of most of the dark regions of the sky." This last statement seems to me to be one of great significance, made as it was by a man who has devoted many years to a study of the dark configurations of the sky.

Professor Barnard states further, in this publication, that he wishes to emphasize the fact that masses of obscuring matter are found in

[1] On the Vacant Regions of the Sky; POPULAR ASTRONOMY Vol. XIV, p. 579.
[2] Astrophysical Journal Vol. 49, p. 14.

other parts of the sky than the Milky Way. In the absence of a star field as a background outside of the Milky Way, the opaque masses of obscuring matter which he has observed are photographed in projection or profile upon a background of sky faintly luminous. "Their apparent preference for the bright regions of the Milky Way," he writes, "is obviously due to the fact that they are more readily shown with a bright background."

It is of great interest to study the photographs of Professor Barnard and to read his interesting descriptions of the images pictured on them. A full appreciation of his work along this line can be had only by consulting the articles which have been written in such standard publications as *Popular Astronomy, The Astrophysical Journal* and, in particular, *Lick Observatory Publications,* Vol. XI.

The dark areas found in definite outline in such irregular nebulae as the Trifid are believed to be due to dark matter which cuts off our view of the nebula beyond (See No. 1 of the accompanying illustrative photographs). The structural detail of the light and dark areas observed in the Orion nebula, their sharp boundary lines and distinctive forms, give every indication of the presence of occulting matter in space which modifies our view of the bright nebulosity beyond (No. 2).

In detail, this evidence is well exemplified and illustrated in the photographs of the Bright and Dark Nebulae south of Zeta Orionis (No. 3). The suggestive features of this photograph may be enumerated as follows:

1. The filmy nebulosity running north and south through its center.
2. Its apparent occultation at the center by a dark cloud whose outline is sharply defined upon a background of nebulosity.
3. The sharp termination of the bright nebulosity at its eastern boundary while on the west it merges gradually into the background of the sky.
4. The dearth of stars to the east of the bright nebula as compared with those to the west of it.

There is every indication in this photograph that here is a region in which our view of the more distant sky is obstructed by non-luminous matter in association with the bright nebulosity shown.

Number 5 of the accompanying illustrations consists of two photographs. The images are placed in juxtaposition here to illustrate the commonly accepted interpretation of photographs of this class of nebulae. Both images are accepted as representing matter distributed in lenticular configuration. In the upper the plane coincident with the center of figure and midway between the two faces of its lens-shaped outline is supposed to be perpendicular to our line of sight, while in

the lower the line of sight lies in or is parallel to the corresponding plane of figure. In other words, the two images may be accepted as representing, in plan and elevation, a typical spiral nebula.

The significant feature of these two spirals, so far as this discussion is concerned, is to be found in the lower. The dark broken line across the image parallel to its longest axis and slightly below its center of figure is accepted as representing dark occulting matter in the circumference of its lens-shaped outline.

A similar dark line or lane has been found on so many photographs of spirals of apparently similar orientation with respect to our line of sight as to establish the probability of there being such a ring of dark occulting matter about all spirals. This dark lane is quite evident in the three photographs assembled in No. 4.

The planetary nebulae differ in many important particulars from the spirals, and yet there are similarities between them which, in all probability, are the results of the action of the same dynamic forces. For example,—taking the Ring Nebula in Lyra (No. 7) as typical—we find that the planetary and the spiral each has a minor and a major axis. Observations indicate that there is rotation about the minor axis in the Ring Nebula and also in some spirals. It is logical to infer that the difference in length between the minor and the major axis may be due to rotation about the minor axis.

The Ring Nebula is believed to be an ellipsoidal body of nebulous material which radiates light from the star at its center and from a peripheral shell whose depth is indicated by the thickness of the ring. The light emitting nebulosity of greatest depth will thus appear as a ring shaped configuration whose plane is perpendicular to our line of sight. As seen in this projection the thickness or depth of the light emitting matter within the ring will be considerably less than in its periphery. It will here be equal only to the thickness of the shell on the side toward the observer plus its thickness on the side opposite. Viewed from any angle at our distance from it, the nebula would still appear as a ring.

If this is a correct statement of the physical condition of this planetary nebula it is natural to seek for an explanation of the darkening of the ring at the extremities of the major axis. If the similarities noted between a spiral nebula and this planetary are of similar origin we may say that the dynamic forces which will produce and maintain a ring of non-luminous matter in the periphery of the plane of the one will be present in the other to maintain a ring of non-lumious matter in its corresponding plane. We infer from the configuration that this plane—the plane coincident with its major diameters—is parallel to our line of sight. In this case the ring of occulting matter, in projection, would lie along the major axis.[3] The greatest depth of occulting matter

[3] "It seems....to be without an exception that any darkening or diminution in brightness takes place along the major axis." Curtis, L. O. Publ. Vol. XIII, p. 65.

would occur at the extremities of the major axis, as viewed from the earth, and in these two positions the occulting matter of the ring would cut off the greatest amount of light from the nebulosity underlying it.

Granting this to be the correct explanation of the darkening at the extremities of the major axis, the outlines of the darkened sections in these positions give us in cross section some indication of the thickness and configuration of the occulting ring.

If such a ring of occulting matter is present, the units of which it is composed are probably in rotation about the minor axis of the figure. As the non-luminous matter composing the ring moves across the underlying nebulosity, a variation in its density would cause a variation in the light of the star at the center of the nebula. It may be mentioned, in this connection, that there are observations at hand which point to its variability. It is worthy of note that, although the light of the central star passes through a great depth of occulting matter, its light is highly actinic. Its photographic magnitude is given as 13, its visual as 15.4. How much brighter the star might be were there no occulting matter before it, is open to question, but judging by the difference in the brightness of the ring at its minor and at its major axis we may reasonably infer that it might be several magnitudes brighter.

The Dumb Bell Nebula is similar in many respects to the Ring Nebula. An inspection of illustration No. 6 would indicate that radiations come from the whole nebulous interior. The projection of the occulting ring may be seen in faint outline at the extremities of the major axis.

We need not necessarily infer that the ring of occulting matter in a planetary nebula is distinctly separated from the underlying nebulosity as the rings of Saturn are from the planet. We might plausibly consider it to be the external boundary of the nebula in the plane of its major diameters. The inference made here as to the distribution of occulting matter in a nebula are based upon a comparison of one region with another. This does not deny the possibility that occulting matter may also be otherwise associated with its various parts, nor that it may completely surround the whole configuration.

Of the photographs taken which exhibit the effects of occulting matter in space none are of greater significance than those of the type exemplified by the Diffuse Nebulosity shown in No. 8. The nebulosity is circular in general outline. The outlying field of stars is relatively dense, while in a circular ring immediately surrounding the nebulosity there is a very noticeable dearth of stars. This ring appears to be nearly uniform and is equal in width, approximately, to the radius of the nebulosity. It is believed to be made up of occulting matter which completely surrounds the nebulosity. The field of stars is supposed to be uniform and continuous. The vacancy in the ring is the result of

the eclipse of the stars behind it.

From the uniform width of the ring and its circular form we infer that the distribution of occulting matter about the nebulosity is spherical. If photographed from any other point in the universe at a distance from it equal to our own, the occulting matter of the surrounding spherical shell would appear on the plate as a ring of similar width. This means, of course, that we are viewing the nebulosity through a depth of occulting matter equal to the width of the ring as shown on the photograph.

We may judge of its effectiveness in cutting off the light of the nebulosity by the dearth of stars in the ring as compared with those in the surrounding field. The nebulosity would undoubtedly be several magnitudes brighter were the occulting spherical shell of matter removed. Of this nebula Dr. H. D. Curtis[4] says: "It seems very clear that the cutting off in the number of stars around such a nebulosity must be due to the presence of occulting and non-luminous matter outside the luminous portion of the nebula."

The probability thus established that a configuration may be enclosed completely by occulting and non-luminous matter which, in very appreciable quantity, decreases the light which we would otherwise receive from it is of such significance as not to be ignored in the discussions of our soundings of the depths of space.

Examples of types intermediate between the spiral and spherical configurations might be added but those already cited are sufficient to point to a possible law of distribution. In the spiral configuration the occulting matter is strongly concentrated in the periphery of its central plane, in the planetary there is a notable condensation of occulting matter toward the periphery of the corresponding plane, while in the spherical distribution the occulting matter appears to be distributed in a sphercial shell about the luminous nebulosity within.

It is to be noted that there might be a shell of non-luminous, occulting matter about a nebulous mass or group of stars without the evidence of it appearing on a photograph of the region. Thus, if most of the stars whose images are projected upon a plate were between us and the configuration photographed there would be no falling off in their number toward it, and if the occulting matter were of a luminosity equal to that of its sky background, there would be no contrast between the two regions to reveal the presence of the non-luminous matter of the region. In the Diffuse Nebulosity (No. 8) the spherical shell of non-luminous matter is detected through the fortuitous circumstance of there being a rich field of stars in the region behind it. There appears to be no difference in luminosity between the ring of occulting matter and the outlying region of the sky, but this point could be determined only by consulting the original photograph.

[4] Publications of the Lick Observatory Vol. XIII, p. 50.

In the Trifid Nebula (No. 1) the occulted areas are notably darker than the surrounding background of the sky, and thus the evidence of occulting matter found in the contours and sharp division lines of the dark areas in relation to the bright nebulosity of this configuration is strongly supported by Barnard's method of detecting non-luminous matter by its contrast on a photographic plate with the luminous background of the sky. A rich field of stars surrounds the Trifid Nebula but there is no such falling off in their number toward the nebulosity as in the Diffuse Nebulosity (No. 8). In fact the star field appears to extend across the nebulosity itself, for star images may be seen projected, apparently, upon its dark areas. We would infer from these considerations that most of the stars of the field are between us and the nebula rather than beyond it. Somewhat similar conditions, both in regard to the contrast of occulted areas with sky background and as to the surrounding field of stars, are evident in photographs of other diffuse nebulosities.

Professor Barnard inaugurated the sky luminosity comparison method as a mean of detecting occulting matter in regions of the sky where stars are few, but the considerations above suggest an equal value for its application in the Milky Way and other regions rich in stars.

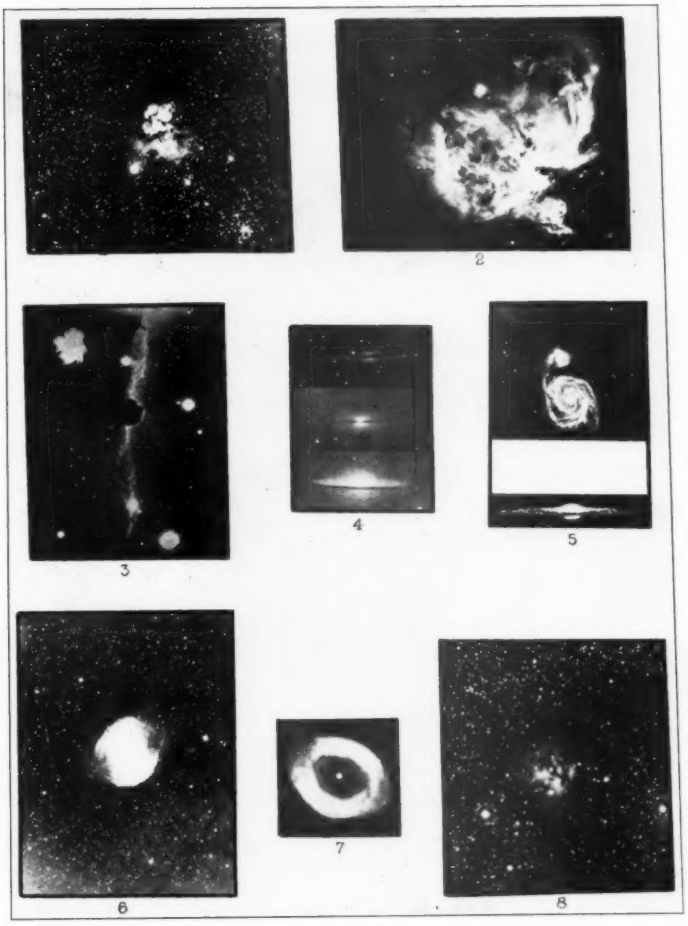
It has already been pointed out that the meteoric bodies which encompass the solar system are suggestive of the nature of the non-luminous matter of space. It is significant also in this connection that, although the light from the star at the center of the Ring Nebula must pass through a considerable depth of occulting matter before it reaches the earth, yet its color index is negative. The stars of the Orion region are rich in radiations from the violet end of the spectrum, yet the observational evidence at hand indicates that their light is notably depreciated by occulting matter before it reaches the observer.[5] These considerations seem to indicate that the occulting matter of space is of such composition as to decrease the light which we would otherwise receive from the stars without producing that change in its quality which it would undergo if it passed through gases. A spectroscopic analysis, in this case, would give no indication of the occultations suffered.

There is further evidence of the presence of non-luminous bodies in the observations of variable stars and spectroscopic binaries. The region about a nova exhibits a nebulosity which, it seems probable, is non-luminous prior to the star's increase in brightness. Such a nebulosity in connection with novae is suggestive of the possibility of a similar nebulosity in association with some of the faint stars and of its contributing to their faintness.

Only in recent years, comparatively, have astronomers recognized

[5] See L. O. Publ. Vol XIII, p. 49-50.

PLATE XI



PHOTOGRAPHIC EVIDENCE OF NON-LUMINOUS MATTER IN SPACE.

1. The Trifid Nebula. From a photograph taken at the Yerkes Observatory with the two ft. reflector.
2. The Orion Nebula. From a photograph taken with the 100-inch telescope at Mount Wilson.
3. Bright and Dark Nebulae near Zeta Orionis. From a photograph taken with the 100-inch telescope at Mount Wilson. For a complete description and full scientific discussion of this photograph see Astrophysical Journal Vol. 53, p. 392, by John C. Duncan.
4. Three Spirals, N. G. C. 891, 7814 and 4594 taken with the Crossley Reflector. L. O. Publ. Vol. XIII, opp. p. 54.
5. Spiral Nebulae. From Mount Wilson photographs.
6. The Planetary Nebula, Dumb Bell. From a Mount Wilson photograph.
7. The Planetary, Ring Nebula. From a photograph taken with the Crossley Reflector.
8. The Diffuse Nebulosity, N. G. C. H 5146. From a Lick Observatory photograph.

that non-luminous matter may be present in interstellar space in quantities sufficient to modify our view of the physical universe about us. As observational evidence along this line increases, a more exact knowledge of its effect, undoubtedly, will be attained. Meanwhile a perusal of the remarkable photographs already at hand which exhibit the presence of non-luminous matter in space will well repay anyone interested in the subject.

A GARDEN TELESCOPE.

By RUSSELL W. PORTER.*

Any efforts toward the popularizing of the telescope would seem to be amply justified, and any improvements tending to simplify its use among amateurs as an astronomical instrument are, of course, to be desired.

One of the drawbacks to the amateur is the setting up and dismantling of his telescope whenever he finds an opportunity for an evening with the stars. The new Garden Telescope has removed this obstacle by a form of mounting that, once set up and placed in proper adjustment, remains a permanent fixture in the garden, requiring no further care. It is always ready for use. Incidentally the mounting which is an equatorial one, has been so designed as to produce a beautiful garden ornament in solid statuary bronze.

Optically the Garden Telescope is a modified Newtonian reflector of six inches aperture, with a focal length of approximately two feet and is provided with eyepieces giving 25, 50 and 100 magnifications. The parabolic mirror is a disc of glass three-quarters of an inch thick silvered on its concave, or front surface. This mirror is provided with a cast bronze cover with machined edges for protection when not in use. The mirror may or may not be taken indoors for safe keeping. At the plant where this instrument is being manufactured the mirror was left outdoors in its mounting through the rigors of a Vermont winter without appreciable deterioration.

It will be seen from the photographs that the familiar telescope tube has disappeared and that the reflecting prism and eyepiece are held in their proper relation to the mirror by a bronze arm in the form of a leaf. The prism and eyepiece rotate around the end of this arm so that it may be brought to any convenient observing position, whether the object viewed be in the zenith or on the horizon.

The mounting itself has several unique features. It is a combination alt-azimuth and equatorial mounting. That is, for day use on

*Jones & Lamson Machine Co., Springfield, Vermont.

terrestrial objects, it may be swung around a vertical axis maintained through a ball bearing track at the base. But for use at night to follow the apparent movement of the stars the base is clamped and the equa-

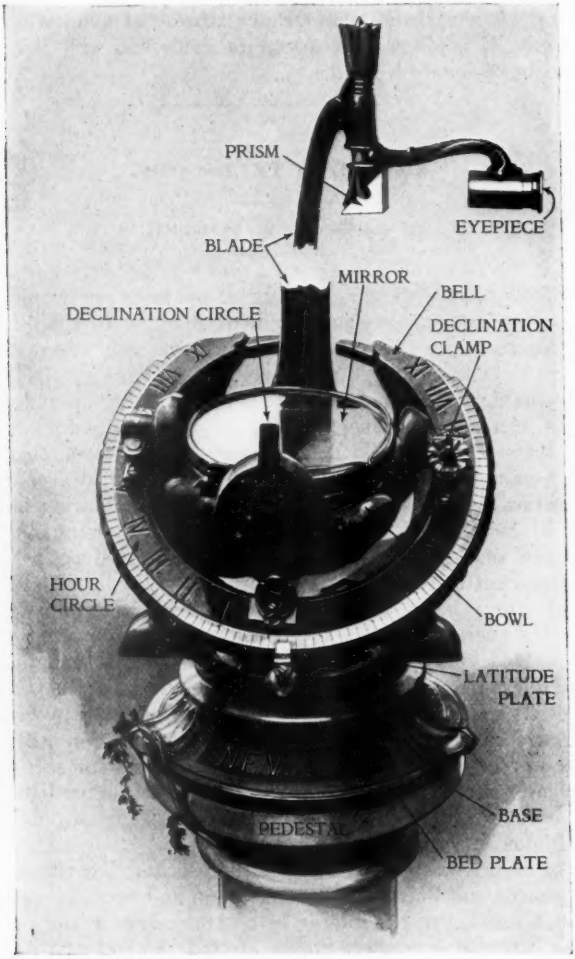


FIGURE 1.—Cut Showing Garden Telescope Details.

torial motion produced by the rotation of the bell. The axis of this bell which carries the bowl and blade is the polar axis of the instrument and is maintained at one end by a thrust bearing and at the other by a circular track on its rim resting on two rolls.

FIGURE 2.—Being a Newtonian Reflector, the Observer Looks at Right Angles to the Direction of the Object Being Viewed.

In the illustration showing the details of the Garden Telescope the various members comprising the mounting are indicated. The declination axis of the bowl turns in bearings cast on the rim of the bell. The bowl is hollow and filled with lead to exactly counterpoise the blade. The declination circle envelops the bowl, on which the declination of the star is laid off. Around the rim of the bell is an eleven inch hour circle graduated into hours and coarse ten minute intervals. In use, the observer gets his watch to running on local star time, and by applying the right ascension of the star to his watch reading, turns off the hour angle by means of the hour circle, into the east or west as the case may be. The object will then appear in the field of view of the eyepiece and its apparent motion across the sky is followed by turning one of the rolls (not shown) on which the bell rim rests.

FIGURE 3.—The Mirror and Eyepiece May Be Taken Indoors for Safe Keeping if Desired.

The instrument is first adjusted so that the axis of the bell is parallel to the earth's axis. For this purpose the latitude plate supporting the bell has a machined spherical seat, which allows a range from latitude 25 to 55 (north or south of our equator). This embraces all of our states as well as Europe, excluding parts of Scandinavia, South America, New Zealand, etc.

A convenient method of accomplishing this adjustment is upon the north star at a certain time during any clear evening, and is described in the printed instructions accompanying the telescope. The declination axis is brought horizontal. Polaris' declination is set off on the declination circle and clamped. The spherical seat is then freed and the base allowed to turn on its horizontal track. Polaris is then brought to the center of the field of view of the eyepiece and the base and spherical seat are then clamped with the set screws provided, and the telescope is in very good equatorial adjustment. It is not disturbed thereafter.

In principle this is the customary way of finding obscure celestial objects with astronomical telescopes. The positions of many double stars, multiple stars, clusters and nebulae, within the range of the

Garden Telescope as well as a table for setting one's watch to star time, with various examples worked out, are given in the setting up instructions.

For day use, however, the telescope is simply sighted at the object as one would point a rifle. Two open sights on the back of the blade are brought to bear on the object whose image will then be found in the eyepiece.

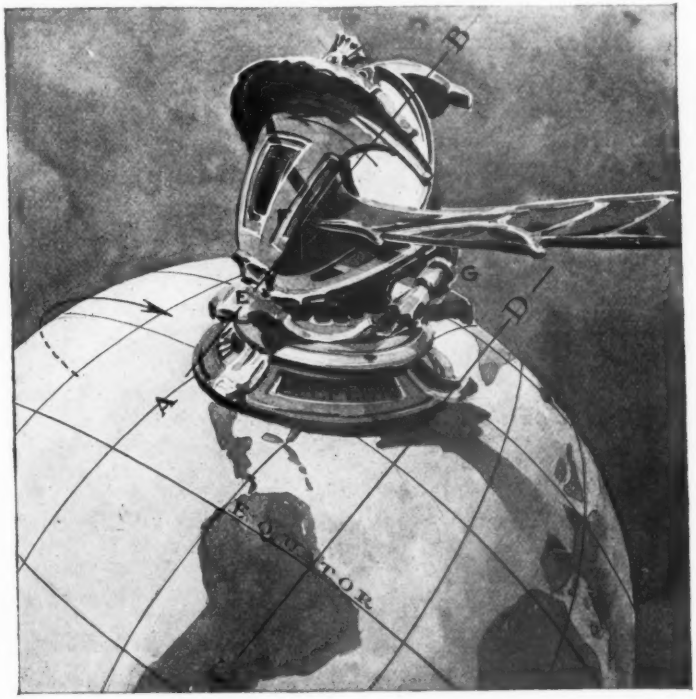


FIGURE 4.—In Adjusting the Garden Telescope, the Axis of the Bell is Brought Parallel to that of the Earth.

It will be noted that a part of the bell has been removed to prevent interference with the blade when used on southern stars. This permits the telescope pointing to any part of the heavens above the horizon. The telescope proper being swung *between* the declination axis bearings instead of overhanging one end, together with the wide three point support of the bell, provides an extremely stable and rigid form of mounting.

The Garden Telescope functions with considerable accuracy as a timekeeper. If the telescope is brought to bear on the sun by project-

ing the sun's image on a card just outside the eyepiece, sun time is read off directly on the hour circle to the nearest minute, to which, of course, the equation of time must be applied to obtain local mean time.

Nearly all sun dial pedestals are suitable for supporting the Garden Telescope, as they are of about the right height and size. Some owners prefer to make their own pedestals of brick, stone or poured concrete. The manufacturers, however, provide, if desired, a pedestal with a locking device for securely fastening the instrument to the pedestal top.

FIGURE 5.—As a Time Keeper the Sun's Image is Thrown on a Card and Sun Time Read Off at Once on the Hour Circle.

There being no iron in the instrument's construction, there is nothing to rust. The surfaces slowly take on the dark olive color of statuary bronze, remaining unaffected by the weather.

This feature of having a moderately powerful telescope on one's lawn always at one's disposal, whether it be to catch and hold a passing aeroplane or to make more attractive the study of the heavens, ought to make this novel garden accessory a familiar object in many gardens. A typical instance of having a telescope "on the job" like a minute man transpired at the shops where the Garden Telescope is made, during the recent eclipse of the sun. One of the telescope makers re-

marked that the eclipse must be pretty well along. Another member jumped into his car and went uptown, and in ten minutes the village photographer had taken several plates, one of which is shown here. The blade was swung on to the sun and its image thrown on a sheet of cardboard, much to the edification of the office force who came out to view the phenomenon.

The large light grasp of the mirror produces a very brilliant and colorless image and the eyepieces are the best obtainable, being the Hastings positive astronomical oculars by Brashear.

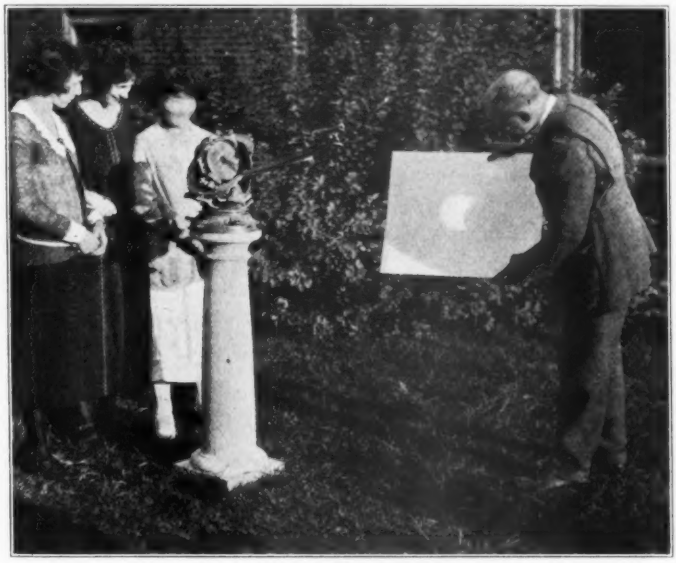


FIGURE 6.—Viewing the Eclipse of the Sun of September 1923.

Recently the manufacturers have added as an accessory, an additional eyepiece, so that two persons may view the same object simultaneously. Each eyepiece is independent of the other, has its own prism, and takes its half of the light producing the image. There is a considerable advantage in this double ocular, for two people may then discuss what they are seeing without one's having to remove his eye to give the other a look.

When the writer prepared "The Telescope Makers of Springfield, Vermont" for POPULAR ASTRONOMY two years ago which described the work done among the mechanics of Springfield in making their own powerful reflectors, he predicted that the experiment might develop into a new industry for the town. The Garden Telescope is the first commercial product of this endeavor.

The cost of the Garden Telescope, while considerable for the amateur, is far below that of a refractor of the same aperture. The mirror may be returned to the makers when desired, for resilvering at nominal cost. The silver coating is covered with a lacquer of gun cotton and amyl acetate to preserve its lustre without detriment to its optical properties. With care the silver coat will last for years.

Readers of POPULAR ASTRONOMY who have followed the writer's various articles on speculum making will be interested to know how the mirrors of the Garden Telescopes are made, when turned out on a production basis. A full description of the process is a whole story

FIGURE 7.—An additional Eyepiece is Provided Whereby Two Persons May Enjoy the Garden Telescope at the Same Time.

by itself. It is sufficient here to state that a machine has been designed to bring to a complete polish a number of glass discs, holding their surfaces very close to that of a concave sphere, the knife-edge test being carried out at the center of curvature of the glass. The parabolizing is then carried on with a specially designed machine, the knife-edge tests now being at the focus, parallel light as from a distant star having been produced in the laboratory. The parabolizing is perfected until all rays reflected from the mirror cross the axis of the glass within one hundredth of an inch of each other. This is equivalent to saying that with the Garden Telescope properly focused on a star, a movement of the eyepiece one hundredth of an inch either way would impair the image. The writer must admit, however, his inability to completely parabolize by machinery. To bring the figure within the specifications he has laid down for these mirrors a certain amount of hand work seems unavoidable.

THE LUNAR ATMOSPHERE.

By WILLIAM H. PICKERING.

The density of the lunar atmosphere may, theoretically at least, be determined by means of occultations. The uncertainty in the process lies not at all in timing or in computing the occultation itself, but rather in determining the diameter of the moon. Lunar mountains rising more than a mile above their immediate surroundings are by no means rare upon the limb. This corresponds to a second of arc in the diameter. When the Oceanus Procellarum is on the limb, that is at least a mile and perhaps more, lower than the highlands, usually seen beyond it. An average has therefore to be struck, and the result secured by a combination of many occultations.

When a star is occulted by the moon, owing to the lunar refraction, however small this may be, the star does not disappear until after it is behind the limb. The occultation value of the diameter is therefore smaller than the real diameter. There is also still a third diameter of the moon that we must know. This is the eclipse value. For an occultation we assume an average size of the disk, but for a total eclipse of the sun we must know the minimum diameter of the moon, so that no ray of sunlight shining through any lunar valley shall be visible around it. This lunar diameter can be determined with very considerable accuracy. The average diameter used for occultations is more uncertain, and the real diameter, determined by transit observations, is known with still less certainty.

By the *American Ephemeris* for 1925, p. XVII, we learn that the value of the semi-diameter of the moon, i. e., the real value, is 15′ 32″.58. Using the formulae given on p. XI, we find for the eclipse semi-diameter 15′ 31″.87, and for the apparent semi-diameter, 15′ 34″.08. Regarding this last value we learn by the note on p. XVII, "For the values of the semi-diameter used in this volume see p. XI." From this statement we might naturally infer that the latter figure which is 1″.50 larger than the real value given on p. XVII, was the one used in the *Ephemeris* for the computation of occultations, etc. Obviously it must be just the other way. The larger value, 15′ 34″.08, is the real semi-diameter, while the smaller one, 15′ 32″.58, is the value which should be used, and doubtless was, for the computation of occultations.

What interests us here however is something else. The *Ephemeris* makes a difference of 1″.50 between these two values, and attributes it to irradiation. To anyone who has observed the moon under favorable atmospheric conditions, it must be obvious that no such large

quantity as 1″.50 can possibly be due to irradiation. This would be from two to three times the width of an average run or canal. With a reasonably high power, such as would naturally be used in measuring the diameter, in order that the moon should not dazzle the eye, the effect of irradiation must be practically *nil*, and the difference of 1″.50 would then be attributed wholly to the refraction of the lunar atmosphere.

When the seeing is poor, such as is found in the north, we find that small bodies like Jupiter's satellites, and also small artificial disks a few seconds in diameter appear smaller than when the seeing is good. We might naturally have supposed that they would appear larger. There is no reason to believe that large bodies like the moon would act differently. Consequently, if with poor seeing the observed diameter exceeds the occultation diameter by 1″.5, then with good seeing the difference would be larger still.

Since the moon is but one-quarter the size of the earth, we should expect the refraction of its atmosphere to be but one-quarter as great. The total terrestrial refraction is double the value of the horizontal refraction. Correcting for the difference in size, the ratio of the lunar to the terrestrial refraction therefore becomes

$$\frac{1''.50 \times 4}{1800'' \times 2} = \frac{1}{600}.$$

Atmospheric refraction is proportional to atmospheric pressure, that is to say, to the number of molecules above us. Hence it does not depend on their distance apart. Accordingly the number of molecules in the moon's atmosphere per square foot of surface, to the number in the earth's atmosphere, is as 1 to 600. Since the gravitative force at the moon's surface is but one-sixth that at the surface of the earth, the ratio of the surface densities will be as 1 to 3600.

The pressure in the earth's atmosphere is reduced one-half by an ascent of every three and a half miles, but in the case of the moon the distance ascended must be six times as great, or twenty-one miles. At an altitude of a little less than 50 miles therefore the densities of the two atmospheres are equal, and at greater altitudes the lunar atmosphere is actually the denser of the two.

While this investigation may thus give us a fair idea of the density of the lunar atmosphere, a modification of a plan which was carried out many years ago should give us much more reliable results. This plan was to photograph the planet Jupiter before occultation, and again just before the first contact of the two limbs. It was recorded that in the second case a slight flattening of the disk was detected in a direction radial to the moon, but that this flattening did not exceed 1″.0 and probably not 0″.5, corresponding to the 1″.50 that we adopted above from the *American Ephemeris*, (*Astronomy and Astrophysics* 1892, 778). It was at that time desired to photograph a fairly wide

double star near occultation, but my telescope with an aperture of only 13 inches was too small for the purpose. With the numerous large reflectors and refractors now extant, and the modern more sensitive plates, it is possible that someone may have sufficient interest in the question to secure some measurements. It would probably be best to partly cover the plate with a darkened film. On this the moon's image would fall, thus greatly reducing its light. A wide cluster such as Praesepe or the Pleiades should furnish an ideal background of stars

Still another feature of interest was observed at this occultation. A dark band 3″ in width was noted tangent to the limb of the moon, and strongly inclined to the planet's belts. This band was observed visually by Professor Douglass, and also appeared on the negatives which I secured, but does not show on the published reproductions. At the reappearance of the planet from behind the dark limb, neither the band nor the flattening of the disk could be detected. It was therefore concluded that the lunar atmosphere was precipitated in a solid form on the night side of the moon. If this is the case, and the refraction of occulted stars occurs only on the illuminated side, we must double the computed density of the lunar atmosphere to one part in 1800 of that of the earth. This difference in the refraction at the two limbs would be a matter of especial interest to redetermine, for more reasons than one. Several years ago Comstock concluded that the refraction at the dark limb was insignificant.

At a later occultation Barnard observed the same dark band across the face of the planet, and attributed it to contrast with the brighter disk of the moon, which was theoretically about six times as bright. In this he was probably correct, but if such were the case, it is difficult to see why the band should have appeared on the photograph. I have always wished to look for it during an occultation of Venus, which is much brighter than the moon, but have never had the opportunity to do so. There will be two occultations of Venus this year, one of Mercury, and one of Mars. The last should be seen under favorable conditions in England, if clear skies can be found in November.

Having now settled the density of the lunar atmosphere, at least approximately, by two independent methods, giving reasonably accordant results, our next question will naturally be, what bearing does the existence of this very rare atmosphere have on the question of lunar life? Probably very little. On the existence of the lunar clouds howver, those shifting, white, hazy masses that conceal every minute surface detail that they cover, the matter is different. How can such clouds exist at so low a pressure? Probably only in the form of ice crystals, constantly renewed from volcanic sources.

With regard to life, even our terrestrial vegetation requires but little free oxygen, and some forms of animal life none at all. They secure the needed supply from their food. Water may well come from volcanic sources, which appear to be far more active and more universally dis-

tributed on the moon than on our earth. These forces however take the form of boiling springs and fumeroles, and perhaps in only one instance, as far as we have observed, show any activity of the Vesuvian type. When we speak of boiling springs we must remember that on the moon water would boil at the freezing point.

Terrestrial vegetation requires large supplies of carbon dioxide gas, and this is supplied to it mainly from our volcanic regions, while comparatively little is furnished by animal life. If when the moon left the earth's side, let us say 400,000,000 years ago, it then carried away with it its fair share of water, and if ever since that time it has been losing water into planetary space at the rate of a cube of water measuring 1000 feet on a side every year, there would still be left in its interior, as has previously been shown, enough water to last 400,000,000 years longer. Thus there seems to be no trouble about either sufficient water or carbon dioxide to last those small areas now supporting lunar life for many years to come.

Mandeville, Jamaica, B. W. I., January 3, 1924.

PHOTOGRAPHY OF THE MOON WITH SMALL LENSES.

By JAMES H. WORTHINGTON.

The accompanying photos of the moon may be of interest because of the extreme simplicity of the means by which they were obtained.

The lens, a single 1½-inch bi-convex of 0.375 diopters having a focal length of 103 inches, was obtained from a local spectacle maker for a dollar.

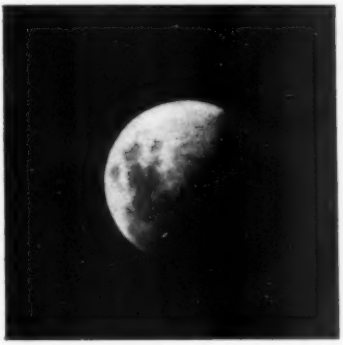
The camera body consists of a rectangular wooden tube, eight feet long, carrying the plate at one end of it. Over the other end a slightly larger tube two feet long is made to slide. This short tube, carrying the lens, is slotted so that when the proper focal length has been found it may be clamped, by means of a wing nut bolt and washer.

The camera was provided with an excellent finder. A single ½ diopter lens of 80 inches focus was stuck in a bit of modelling clay, near the upper end of the tube. The moon image from this finder fell upon a paper screen beside the plateholder.

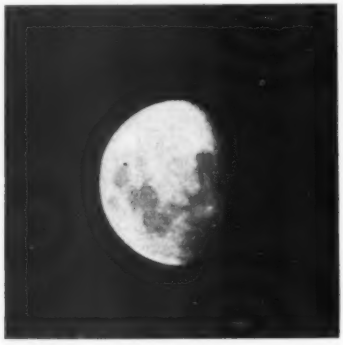
The photographic focus of the camera lens is an inch or so shorter than the visual. A few trial plates determined it.

With a seed ortho non-halation plate the best exposure for the moon was found to be about three-quarters of a second. Exposures were made by lifting a hat off the end of the camera.

The object of the experiments here described was to devise simple and cheap cameras which would give useful photographs of the totally eclipsed sun. The moon is a good trial object, being of the same order of brightness as the inner corona. Results show that good cameras can be made with 1½-inch single lenses of two, one, or a half diopter, which have foci about twenty, forty, and eighty inches, and giving moon pictures two, four, or eight tenths of an inch in diameter. Experiment shows that if the maximum exposures do not exceed eight, four, and two seconds respectively, the images are not intolerably blurred by the diurnal motion.



Moon 8.24 Days Old.
Exposure ½ second.



Moon 10.24 Days Old.
Exposure ¾ second.

PHOTOGRAPHED WITH SINGLE LENS, 1½-INCH APERTURE, 103 INCHES FOCUS, WITHOUT DRIVING.

The light speed of the cameras varies inversely as the square of the focal lengths—so that the shorter cameras will grasp fainter detail though they show it on a small scale.

Gathering our results into a table we have the following data for a 1½-inch camera:

Dioptric Power	Focal Length	Size of Moon Image	Exposure for Moon	Max. exp. without Blur	Light grasped at Max. exp. objects
½ diopter	80 in.	.8 in.	1/2 sec.	2 sec.	4 times fainter than moon.
1 diopter	40 in.	.4 in.	1/8 sec.	4 sec.	32 times fainter than moon.
2 diopter	20 in.	.2 in.	1/32 sec.	8 sec.	256 times fainter than moon.

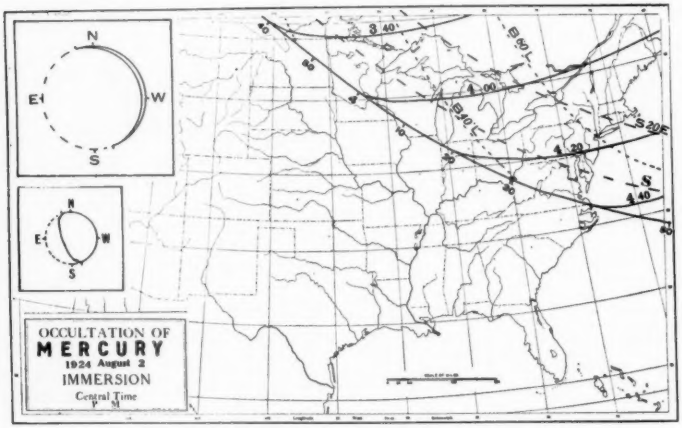
The table shows that good pictures of the corona may be expected from these simple cameras, without any equatorial mount.

Box 572, Carmel, Calif. 1923 July 26.

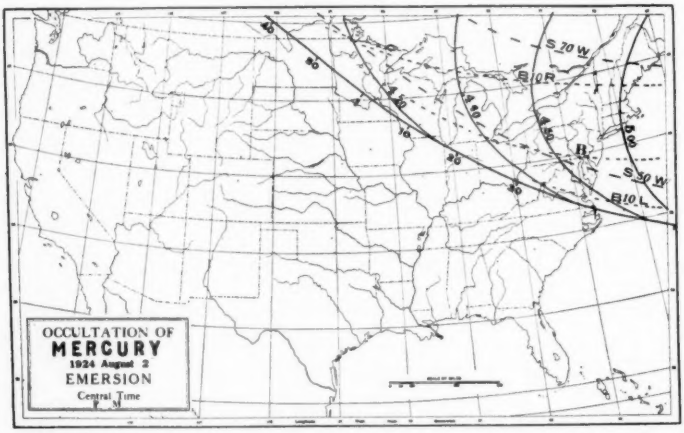
OCCULTATION OF MERCURY 1924 AUGUST 2.

By WILLIAM F. RIGGE.

Both inferior planets, Mercury and Venus, will be occulted in August. But the circumstances are more or less unfavorable for both. Only a small number of the states will get to see them. The occultation of the



first will take place in the day and near the sun, and that of the other at a very early hour of the morning.



The occultation of Mercury will occur on August 2, in the day time, and will be visible only to the northeastern states. The moon will be a

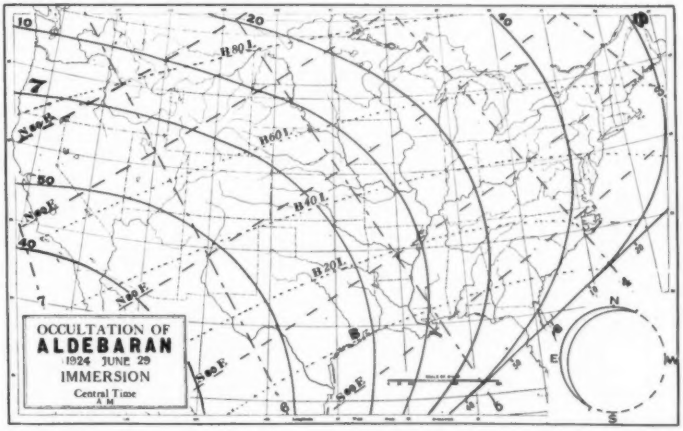
very slender crescent, only 2.1 days old, and nearer the sun (24°) than in any other of the occultations of these years, so that there may be a contest between the skill of the observer and the quality of his telescope as to whether the occultation will be seen at all. The diameter of the planet will be 6″ and its stellar magnitude 0.2. It will be on the farther part of its orbit and gibbous in phase.

On the annexed maps the full lines from 3:40 to 4:40 give the standard times of the immersion and those from 4:20 to 5:00 the times of the emersion. The dashed lines show the position angles from the south point towards the east and west, and the dotted ones those from the bottom B towards the left and right. The numbers on the limit line indicate the times of the grazing contacts. The inserts in Fig. 1 show the phases of the moon and of Mercury. These are not drawn to the same scale, of course, as the moon's semidiameter 924″ is 308 times Mercury's 3″. The north cusp of the moon is 19° 7′ east of its north point. The widest part of the crescent is 0.09 of a lunar semidiameter.

OCCULTATION OF ALDEBARAN 1924 JUNE 29.

By WILLIAM F. RIGGE.

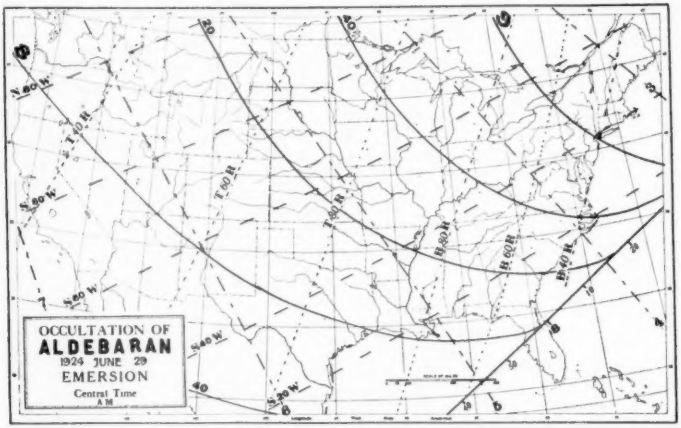
This is a daylight occultation. But instead of occurring near noon, like the one of last April 8, the phases will be spread over almost the entire morning, the immersion taking place at sunrise on the Pacific



coast, and the emersion at about two hours before noon in the Atlantic states.

On both maps the full lines give the times to every ten or twenty minutes, the large 7, 8, 9, meaning 7, 8, 9, A. M. Central Time. The

dashed lines indicate the position angles from the cardinal points N, S, E, W, while the dotted ones show them as measured from the top, bottom, left, and right of the moon's disk, T, B, L, R. The lines that are both dashed and dotted and marked 3, 4, 5, 6, 7, at the bottom,



indicate the full hours of the central time of sunrise. The insert gives the phase of the moon. This is a slender crescent 27.0 days old, or 2.5 days from New, and 30° away from the sun. The north end of the lunar terminator is in position angle N 25° 3′ W.

THE BRIGHTNESS OF LUNAR ECLIPSES, 1860-1922; AN ATTEMPT TO USE THE ECLIPSED MOON AS AN AEROLOGICAL INDICATOR.*

By WILLARD J. FISHER.

The observational data on lunar eclipses, published by professional astronomers and amateurs, for the period 1860-1922, have been read, and have been collated, as far as possible, without reference to any theory of the illumination of the eclipsed surface. Of over 1000 references collected, more than 325 have been found usable.

A scale of brightness adapted to the data has been devised, consisting of three grades: grade 2, details on the eclipsed surface visible with hand instruments or to the naked eye; grade 1, details visible with apertures of 2 to 6 inches, but not with less; grade 0, apertures of 6 inches or more needed to show detail.

This scale has been applied to all suitable data for each eclipse.

*Abstract of a paper read before Section B of the American Association for the Advancement of Science, Cincinnati.

On account of curious discrepancies in the reports of both amateur and professional observers, the grading has been frequently somewhat arbitrary.

In the hope that the varying masses of air along the ray might prove to have an effect in causing these discrepancies, the relative air-mass has been computed for each important report used in grading, and the reports under each eclipse have been arranged in order of increasing air-mass; but there seems to be no well-defined connection.

Assuming that the grades thus assigned are significant, the data have been selected and arranged in several sequences, to test the relation of various astronomical and accidental causes to the brightness of the eclipsed moon.

It is found that the position of the moon's path with regard to the center of the shadow is significant; when the moon passes clear of the center on the south side, the shadow is brighter, mean grade 1.62; when it passes over the center, less bright, mean grade 1.32; when it clears the center on the north side, decidedly dim, mean grade 0.64.

This is shown not only for all 68 eclipses, but also for 13 pairs of consecutive eclipses.

In 37 total eclipses, there seems to be no very decided effect of distance; on the average, the shadow at middle distances is perhaps somewhat brighter than at perigee or apogee.

In 37 total eclipses there is a marked effect of the seasons, which are implied in the longitude of the shadow; winter eclipses, December to March, have been bright, mean grade 1.89; spring eclipses dim, mean grade 0.91; summer and autumn eclipses intermediate and not very different, on the average. No seasonal distribution of dust has been found to explain this, perhaps because the data on dust are insufficient.

The effect of volcanic dust haze in the three great atmospheric disturbances, named for Krakatoa, Pelée and Katmai, has shown itself in the average dimness of 10 included eclipses, mean grade 0.80, as compared with 42 eclipses, 1880-1922, not occurring in the disturbed periods, mean grade 1.36.

If all the southern eclipses are removed, the difference between the brightness of the eclipses in the disturbed periods, mean grade then 0.50, and of those outside them, mean grade then 1.18, is increased. It is as if the northern part of the shadow were specially affected by these disturbances, and were also in general darker than the southern part; which would imply that the atmosphere in high northern latitudes is more opaque, in high southern latitudes more transparent, than in low latitudes.

The average difference between winter and spring eclipses is perhaps increased by the absence of winter eclipses during the disturbed periods.

During the period discussed there is no discernible relation between the solar cycle and the brightness of lunar eclipses.

THE ERRORS WHICH MAY BE EXPECTED IN RADIO LONGITUDE DETERMINATIONS BY THE AUTOMATIC SENDING AND RECEIVING APPARATUS.*

By E. A. ECKHARDT.

In a measurement of the longitude difference between two points on the surface of the earth, simultaneous values of the local time at the two points must be known. A field party in measuring the longitude of the place where it is operating makes the local time observations astronomically and records them on a chronograph. The local time of a reference meridian is conveniently obtained by recording the radio time signals transmitted on a definite schedule for this purpose. A good chronometer serves to bridge the time interval which elapses between the star observations and the standard time signals.

At the signal transmitting station the astronomically observed time and the time signals of the transmitting clock are compared and correlated with the Riefler clock or other standard time-piece. This process as well as the control of the radio transmission by the transmitting clock involves the use of a number of relays. The transmitting clock itself should control directly only a fraction of a watt, if reaction upon its rate is to be avoided, whereas the radio transmission itself requires the control of many kilowatts. A relay system is therefore inevitable.

A study of the development of modern high-speed telegraphy indicates that the speed limitations in transmitting and receiving are due to the mechanical operations involved or are directly related to them. Relays and the manner of their use present the most serious possibilities of lag and error.

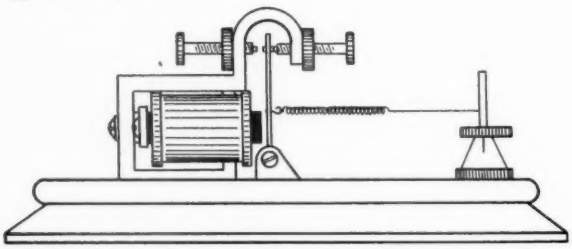


FIG. 1.

The ordinary electro-magnet relay of the type shown in Figure 1 enters into time-signal work in many places and a brief discussion of

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some of its characteristics of operation will lead us to certain general conclusions regarding possible sources of error involved in its use. For convenience we shall refer to the circuit which includes the relay coils as the control circuit and that which functions through the relay contacts we shall call the controlled circuit. If we assume the control and controlled circuits to be completely independent electrically, there are four ways in which the relay may operate to transmit a signal. These four modes of operation are obtained by the possible combinations of make and break of the two circuits. Of these four modes there is one which leads to a minimum time lag. It is the break-break combination. This superiority was established by direct measurement and follows logically from an analysis of the problem.

If we were to lock the armature between the contact screws, an oscillograph record of the current through the relay coils at make and break would have the appearance indicated in Figure 2. The striking

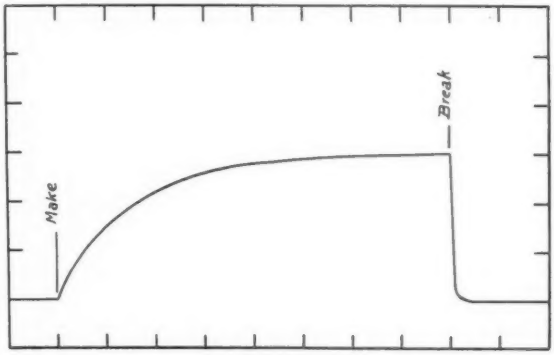

FIG. 2.

feature is the comparative rapidity of the current decay on breaking the circuit. In other words the control circuit is quicker on break than on make. The rate of change of current is determined by the ratio of inductance to resistance of the circuit, being greater the smaller this ratio. At make and break we deal with the closed circuit and open circuit resistance respectively. Since the latter is very much larger than the former the break circuit performance would be expected to be the faster.

The break-break mode of operation of a relay is the fastest for the following reasons:

1. The control current changes at the greatest possible rate.
2. A minimum of armature motion will result in the break of the controlled circuit.
3. The current in the controlled circuit changes at the greatest possible rate.

4. By using larger control currents and correspondingly larger spring tensions the required motion of the armature (item 2) may be accomplished in smaller times.
5. The uncertainties of lag due to "chattering" are eliminated.

The consistency of operation of a relay may be improved by using ground pivots and jewelled bearings. By using all of the precautions suggested, we have found it possible to have a relay control a circuit with an extreme variation in time of less than .0001 second.

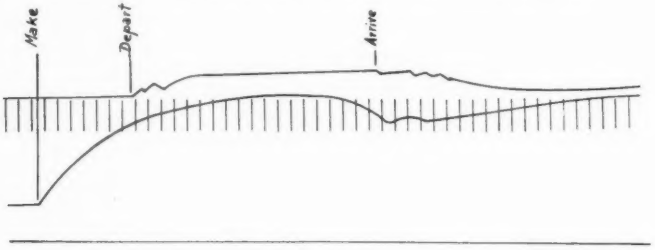

FIG. 3.

Figure 3 is taken from an oscillograph record and shows in the lower trace the current through the control circuit and in the upper trace the current through the controlled circuit in a "make-make" set-up. The vertical lines represent the time scale. Each interval between two adjacent lines corresponds to .001 second. The record shows that the armature does not begin to move ("depart" from its stop) until approximately .0075 second after the control circuit is made. The irregular nature of the current growth curve (upper trace) is due to the microphonic behavior of the contact. Approximately .0185 second later the armature arrives at the inner contact at the point marked "arrive" in Figure 3, and "makes" the controlled circuit. The time involved is long in this case because the contact spacing used permitted the armature contacts to move about 0.1 of an inch.

An interesting feature of Figure 3 is the depression of the current in the control circuit just preceding and during the arrival of the armature. This is due to the back E. M. F. developed by the motion of the armature. In fact the chattering of the contact evident in the upper trace can be followed by its effect upon the current in the control circuit. After the armature ceases to move, the control current again grows regularly, at a decreased rate however, because of the increased inductance of the control circuit.

Figure 4 is an oscillogram of a "break-break" set-up. It shows the rapid decay of the control current on break, and the resulting break of the controlled circuit as well as the chattering which occurs when the armature strikes the stop at the end of its motion.

The oscillograms shown in Figures 3 and 4 illustrate a method which lends itself admirably to the very accurate study of the lags of relays

and electrical circuits. In estimating the lags and errors which enter into radio transmission and reception of signals this method is much to be preferred over statistical ones because the latter reveal nothing

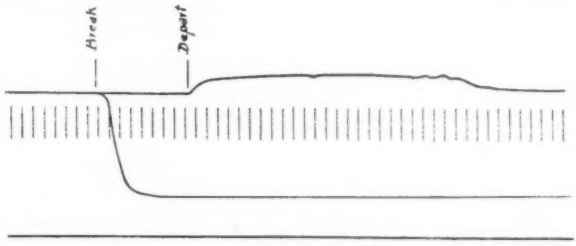

FIG. 4.

regarding the underlying causes. From a study of a number of records obtained under a diversity of operating conditions, conclusions may be drawn as to the best adjustments for operation.

In Figure 5 are shown five curves of current growth, on make, in the control circuit of a relay. From the lower to the upper curve the maximum values to which the currents rise are in ratio of 1 : 2 : 3 : 4 : 5. The horizontal line *oo* represents the current value which is just sufficient to cause the armature to operate. The abscissae of the intersections give the lags involved. The lags for the largest current shown is only one tenth of that for the smallest. While Figure 5 re-

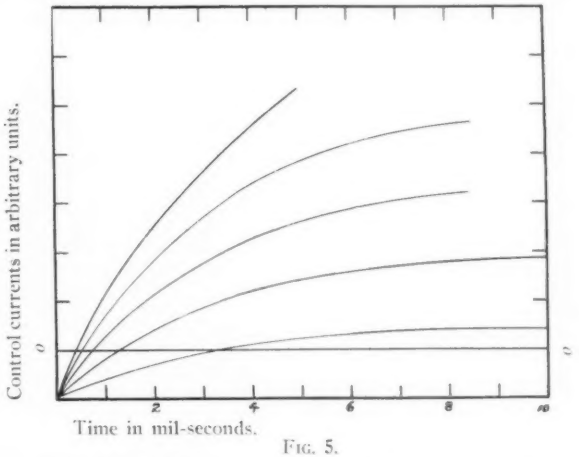

FIG. 5.

fers to somewhat idealized conditions, the conclusions derivable from it are applicable to actual conditions to a first approximation at least. It is obvious therefore, that if variation of lag with strength of operating current is to be avoided, this current should be from three to five

times the threshold value. This variation of lag with current strength indicates that where accuracy is desired care should be exercised in maintaining the operating current at a fixed value. The still prevalent practice of specifying the relay resistance and the number of dry cells used is to be strongly condemned for this reason. The dry cell voltage drops with the age of the cell and consequently the operating current also. Apparent seasonal variations in time signals might possibly be correlated with the periods of dry cell replacement.

In recording time signals by radio a relay is often included in the plate circuit of an ordinary receiving set, the increase of the plate current with the signal being sufficient to operate a relay. These current increases in general vary with the signal strength and are frequently but little above the threshold value for the relay. It follows therefore that there is a variation in lag with signal strength. This difficulty is avoided if the radio receiving circuit is itself of the relay type, that is, if to a first approximation, the current which operates the relay in the plate circuit is independent of the signal strength. This is the case in a radio time signal recording device developed several years ago by J. C. Karcher and the writer[1] for the recording of time signals by the U. S. Coast and Geodetic Survey in its field operations. A second feature of the apparatus referred to is the use of the same chronograph pen for the recording of all signals, radio and otherwise. Identity of the lags for the two kinds of signals which enter into a longitude determination is made more certain by this expedient. In other forms it has been used by Abraham,[2] Urie,[3] and possibly others.

The electron tube lends itself admirably to use as a relay[4] so that a small current in the control (grid) circuit gives rise to a very much larger current in the controlled (plate) circuit. This action takes place without any mechanical motions and the lags may be made so small as to be safely ignored in any time signal work. Wherever great accuracy is desired, the use of this type of relay should be seriously considered.

A marked advance in the elimination of electro-magnet relays as far as possible has been made in some recent devices for the accurate recording of time signals for purposes of longitude determination. Messrs. Abraham and Planiol[5] have developed a very ingenious device of this kind employing eight electron tubes. An apparatus of this type however, while admirable in a fixed laboratory, would not seem to lend itself to field operations. The opinion has been expressed that possibly better results might be obtained by making the time observations at

[1] E. A. Eckhardt, J. C. Karcher, *Journ. Wash. Acad. Sci.* Vol. II, pp. 303-311, July 1921.
[2] Henri Abraham and Rene Planiol, *L'Onde Electrique* Vol. I, pp. 18-25, January 1922.
[3] Frank D. Urie, POPULAR ASTRONOMY, Vol. 31, pp. 91-92, February 1923.
[4] L. B. Turner, *Electrician*, Vol. 83, pp. 4, 5, 34, 35, 554-557, 1919.
[5] loc. cit.

field observatories instead of at the large fixed institutions.[6] If this procedure should be adopted in any comprehensive plan of longitude determination the radio time-recording system now in use by the U. S. Coast and Geodetic Survey would meet requirements as to accuracy with an exactness fully equal to that attainable for the other measurements involved.

Bureau of Standards, Washington, D. C.

REVIEW OF SUNSPOT OBSERVATIONS MADE AT ALTA, IOWA, DURING THE YEARS 1921, 1922 AND 1923, AND BRIEF SUMMARY FOR PAST THIRTY-THREE YEARS.

By DAVID E. HADDEN.

My last communication to POPULAR ASTRONOMY on Review of Sunspot Observations was for the years 1907 to 1913 published in POPULAR ASTRONOMY for March, 1914. Those for the years 1914 to 1920 were included in a paper contributed to the Iowa Academy of Science (Proceedings Vol. 28), and the present review of years 1921 to 1923 completes a series extending over 33 years.

The last maximum occurred about September, 1917, and the gradual decline set in the following year, and was very noticeable in 1920.

1921.

The principal disturbance of this year was the giant group of May 7 to 20, following a comparatively quiescent period, a wonderful group of the two-spot variety was the seat of great activity especially on the 11th and 12th, and culminating on the 14th and 15th, when the group was near the center of the visible disc. Aurorae and magnetic effects beginning in afternoon of 14th continued until after midnight of 15th; widespread disturbances of the telegraph, telephone and cable lines were noted in America and Europe; locally telephone operators experienced difficulty in keeping drop numbers in place on the switchboard. The spectroscope disclosed brilliant flames and reversals in the Hα line in the afternoon of 15th which at 4:30 P. M. had almost subsided; the aurora visible in the late evening of 15th was very beautiful. This disturbed condition of the sun was followed by a marked period of quiescence, some spotless days being noted each month from August to December.

On July 25, a region of facula mottling was noted near the sun's north pole about latitude 80 degrees.

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[6] Wm. Bowie, Special Publication No. 92, U. S. Coast and Geodetic Survey.

1922.

On thirty-nine per cent of the observing days the sun was spotless this year, and every month except March showed an increasing number of such days and a smaller number of spot groups.

A large group in north latitude was on the central meridian March 1 and was spectroscopically active with associated aurora visible in the evening. On the 3rd the groups were all larger and very fine, covering a large area of the disc, but on the 8th another fairly large group, which had appeared by rotation and was about three days from the eastern limb in north latitude, was the location of very brilliant $H\alpha$ reversals, and with the slit widely opened the outline of a wonderfully intricate prominence was seen overlying the group. It was intensely brilliant in the hydrogen lines and could be seen through deepening haze and light clouds for some time. I communicated the observation to Prof. F. Ellerman of Mount Wilson Observatory for confirmation, but he replied that seeing and clouds interfered with their observations, so he was not fortunate in photographing this interesting eruption.

A period of decreasing activity set in after the disappearance of these early March groups, with spotless days during the month of April and, with the exception of smaller but active groups in early May, the disc was mostly clear until the latter part of July. August and September were quiet, but in October from 18 to 21 an active group developed on the disc about 5 degrees south latitude and passed the west limb by rotation spectroscopically much disturbed on the 21st. This spot group returned in early November and again during the closing days of the same month. The year closed with a very large group making the transit.

1923.

Spotless days increased to forty-eight percent of the observing days this year. No group of the first magnitude was observed and the occasional moderate sized ones which were visible in June, September, October and November were rather short-lived.

On July 30 a group ushering in the new cycle of sunspot activity was noted just within the limb at about 28 degrees south latitude. It was short-lived and on August 1 was invisible, but a spot was again noted in this region September 2, when it was a little east of the central meridian. It finished the transit of the disc on September 9. A third transit occurred from September 23 to October 5; a fourth returned October 21, after which it gradually faded out.

A period of long quiescence set in, beginning December 2 and continued during January, 1924, and until the present writing in February, no spots being seen during this interval with the exception of December 18 to 26. Undoubtedly the actual minimum will be reached during the early part of the present year, 1924.

In the following tables are given the monthly summaries of the daily observations taken from January, 1921, to December, 1923.

Months 1921	Number of Observing Days	Average Number of Groups	Average Number of Spots	Average Number of Faculae	Number of Spotless Days
January	7	2.6	13.0	3.1	0
February	14	1.8	9.3	2.5	0
March	16	2.1	7.0	2.5	2
April	11	2.4	9.0	3.2	1
May	16	1.5	6.2	3.0	1
June	15	2.0	11.5	2.2	0
July	11	2.5	15.0	2.4	0
August	13	1.5	6.5	2.0	4
September	15	1.3	6.7	2.3	4
October	18	1.3	5.4	1.6	5
November	13	1.0	3.1	1.4	5
December	12	1.3	8.0	1.7	3
1922					
January	8	1.1	3.5	1.6	2
February	9	1.5	6.1	1.7	1
March	16	2.8	22.0	1.7	0
April	15	1.1	3.1	2.0	8
May	13	0.5	2.8	1.2	6
June	16	0.7	2.1	1.4	9
July	9	1.1	5.0	1.3	3
August	12	0.4	2.5	0.7	8
September	16	0.4	1.0	0.6	9
October	20	0.8	2.6	1.0	8
November	14	0.8	2.4	0.9	4
December	13	1.4	6.8	0.7	4
1923					
January	10	0.5	1.2	1.7	6
February	8	0.0	0.0	1.2	8
March	12	0.4	2.2	0.6	7
April	21	0.5	1.8	0.9	12
May	14	0.4	1.1	0.7	8
June	12	0.9	5.8	0.8	4
July	13	0.5	1.4	0.8	8
August	10	0.0	0.0	0.5	10
September	17	1.2	5.5	0.8	2
October	22	1.1	3.0	1.0	2
November	18	1.0	5.0	1.0	4
December	16	0.3	1.2	1.0	12

Average yearly number of groups for the thirty-three year period.

Year	Average Number of Groups	Year	Average Number of Groups
1891	2.9	1908	3.4
1892	5.6	1909	2.9
1893	6.6	1910	1.3
1894	5.6	1911	0.62
1895	5.2	1912	0.36
1896	3.2	1913	0.14
1897	2.2	1914	0.95
1898	2.1	1915	3.0
1899	1.1	1916	4.5
1900	0.7	1917	7.3
1901	0.25	1918	5.7
1902	0.37	1919	4.5
1903	1.65	1920	2.4
1904	3.1	1921	1.8
1905	4.0	1922	1.0
1906	3.8	1923	0.6
1907	3.8		

Reviewing the observations of the thirty-three years the following dates have been derived:

Minimum of 1889.6 to the maximum of 1893.7	4.1 years,
Maximum of 1893.7 to the minimum of 1901.5	7.8 years
Minimum of 1901.5 to the maximum of 1905.9	4.4 years
Maximum of 1905.9 to the minimum of 1913.5	7.6 years
Minimum of 1913.5 to the maximum of 1917.7	4.2 years
Minimum of 1889.6 to the minimum of 1901.5	11.9 years,
Minimum of 1901.5 to the minimum of 1913.5	12.0 years
Maximum of 1893.7 to the maximum of 1905.9	12.2 years
Maximum of 1905.9 to the maximum of 1917.7	11.8 years.

Astronomical Observatory, Alta, Iowa, February 13, 1924.

THE ECLIPSE OF JANUARY 24, 1925.

By E. A. FATH.

The total eclipse of the sun which will occur on January 24 next will be visible in the most densely populated part of the United States. The path of totality begins in northern Minnesota and, after crossing the states of Wisconsin, Michigan, New York, Pennsylvania, New Jersey, Massachusetts, Connecticut and Rhode Island, passes out on the Atlantic Ocean and ends midway between Iceland and the Scandinavian Peninsula. Fig. 1 is copied from the *American Ephemeris* for 1925 and Fig. 2 is drawn from data obtained from the Eclipse Supplement of the *Ephemeris* for the same year.

Many observatories are fortunate enough to be located within the path of totality. Among these are the observatories of the University of Toronto, Cornell University, Vassar College, Wesleyan University and Yale University. Yale is especially fortunate in being exactly on the central line of the eclipse path.

Many other observatories whose locations are given in Fig. 2 are not very far from the eclipse track.

Two things are against really satisfactory observations, the time of year and the low altitude of the sun. The following data, taken from the *Supplement,* will be of interest:

	Mean January Temperature	Percentage of clear days	Alt. of sun at mid-eclipse	Duration of Totality
Duluth, Minn.	8°	33	2°	A few seconds
Buffalo, N. Y.	25	6	13	1^m 48^s
Ithaca, N. Y.	24	17	14	1 54
New Haven, Conn.	28	32	18	2 0
Block Island, R. I.	31	27	19	2 0

Duluth is just inside the southern limit of the eclipse path, the other stations are on or near the central line. From the above data it is

evident that no elaborate expeditions are likely to be organized, although small ones may be planned.

The large number of amateur astronomers in the eastern part of the

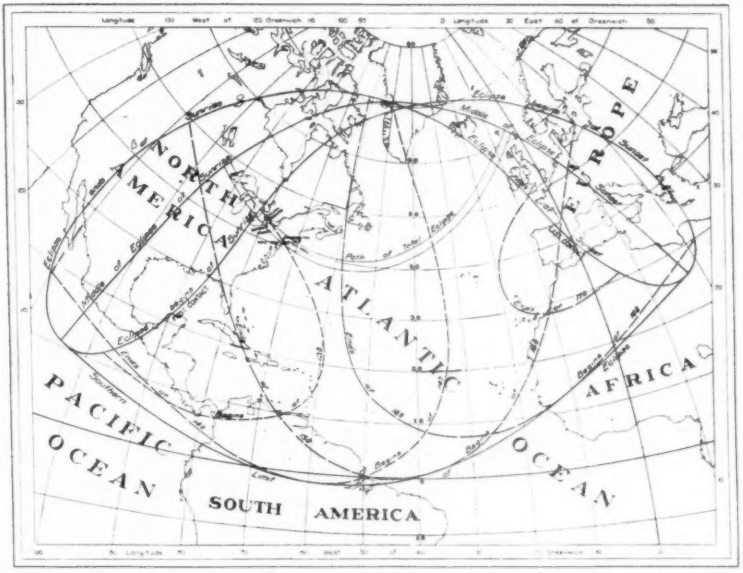


FIG. 1. DIAGRAM OF THE TOTAL SOLAR ECLIPSE OF JANUARY 24, 1925.
The hours of beginning and end are expressed in Greenwich Civil Time.

country will no doubt be greatly interested in the eclipse, as it will be the only one visible in the United States until September 9, 1945, and many may be willing to take a chance on the weather and travel to the central line. Simple cameras with lenses of 30 inches focus or over could be mounted on portable equatorials and used to photograph the corona. Short exposures of about five seconds duration could be made with fixed cameras, as the motion of the sun in that time would hardly be appreciable. The interesting results which might be obtained with spectacle lenses, as shown in the article by Mr. J. H. Worthington on another page of this issue, deserve earnest consideration by those who care to spend $5.00 for equipment. A one-diopter double-convex spectacle lens at one end of a light wooden box and a small plate holder for 3¼ x 4¼ or 4 x 5 plates at the other end would answer the requirements. The box must, of course, be light-tight and the inside should be painted a dead black.

Another instrument which can easily be made is a spectrograph to photograph the flash spectrum. One or two good 60° prisms of about

FIG. 2. DIAGRAM OF PATH OF TOTAL SOLAR ECLIPSE 1925, JANUARY 24.

one inch aperture and a camera lens of from 15 inches to 25 inches focus will be all the optical parts required. Figure 3 shows the plan of the spectrograph. The instrument can be made of light wood, painted dead black on the inside and an opening just large enough to admit the full beam cut in the corner of the box if one prism is used, or in the side if two prisms are available. With an instrument of this kind, using two prisms of 1½ inches aperture and a camera lens of 30 inches focus, Dr. H. C. Wilson secured a photograph of the flash

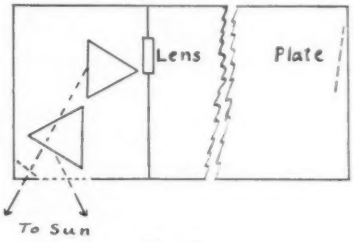


FIG. 3.

spectrum in Colorado at the eclipse of June 8, 1918, upon which it was possible to measure 1008 bright lines.

The spectrograph is not as easily set up as a camera, for it is necessary to know the position angles of second and third contacts and have the length of the spectrum parallel to the solar radii drawn to the contact points. The reason for doing this is that it is desirable to have the crescents cut the length of the spectrum at right angles. Along the central line of the eclipse path these two radii will form a diameter but at points away from the central line such will not be the case and the spectrograph would have to be turned between the two contacts.

Another difficulty comes in making the proper exposures. If, at second contact, the exposure is begun a second too early the continuous spectrum will be too strong. The best chance for success comes at third contact. An exposure of from one-half to three-fourths of a second made immediately after the first ray of sunlight appears should give a good flash spectrum on moderately fast plates.

For the determination of focus and plate-tilt a ground glass will serve, using the uneclipsed sun as a source of light. No lines will be visible, but the edge of the spectrum will serve the same purpose. If this is sharply defined along its entire length the correct focus is assured.

Another line of work requiring very little equipment was suggested by Prof. W. H. Pickering in POPULAR ASTRONOMY for June-July, 1923.

Shadow bands, drawings of the corona and telescopic examination of the details of the inner corona and prominences are also of interest.

Anyone planning to observe the eclipse will find the *Eclipse Supple-*

ment of the *American Ephemeris* for 1925 of great value. It contains a map of the eclipse region on a scale of 40 miles to the inch, detailed information as to the probable weather conditions, a chart of the stars in the neighborhood of the sun and many tables of great value. It can be obtained from the Supt. of Documents, Government Printing Office, Washington, D. C., for 30 cents a copy.

POPULAR ASTRONOMY will be glad to publish the name, address and eclipse location chosen by anyone who will furnish the information, whether a subscriber or not. If the location has not been decided upon but a decision reached to attempt the observation of the eclipse, the publication of name and address may be of service in the formation of groups of observers at various points along the line of totality.

ERATOSTHENES, No. 5.
Darkness, Snow, and Color.

By WILLIAM H. PICKERING.

It will facilitate the reader's understanding of this paper, particularly of those portions dealing with the moving spots, bright and dark, to have before him the maps of the southern rim of the crater in the Eratosthenes oasis. These will be found in our fourth paper, published in the February number of this journal, for the present year. Our second paper to which reference is also made was published in 1921, **29**, 404.

To indicate the different shades of darkness observed on the moon, the following scale of fifteen numbers has been employed. Shadows are indicated by the number 1, various degrees of gray by the numbers from 2 to 10 inclusive, 6 representing the average mare. The bright regions are represented by the numbers 11 to 14, while the small area 1″ in diameter in the center of the floor of Aristarchus, certain mountain slopes about the south pole, and the inner walls of several of the snow craterlets by 15.

It would be interesting to have the temperature of one of these very small areas determined by some of the methods now employed in stellar research. The difficulty hitherto has been that all of these white areas are so very small, only a few seconds in diameter, that their low temperature is completely masked by the relatively high temperature of the surrounding regions. There are larger areas that are moderately bright, 13 and 14, whose temperature is also probably low, but the fundamental tests should be made on the brightest regions. The largest very bright region appears to be the inner wall of Mösting A, which is about 5″ in diameter. A small area on the floor, generally accompanied by a narrow run leading to the north, is dark, but these dark areas are so small, shortly before full moon, that it is believed

that their influence would not be very great. This area of snow, or more properly speaking frost, is very thin, so that soon after full it begins to turn yellow. This is presumably due to the frost melting, and showing small portions of the rocks lying beneath it. Tests should therefore be made at, or just before full moon.

Since it is possible that many sidereal astronomers, unacquainted with the moon, may still feel that the brilliant summits of the central peaks of so many of the craters derive their whiteness from white quartz, or marble, or shiny mica, that just happens to lie only on their summits, it may be well to call their attention here again to the change in size and azimuth of the white area on the highest summit in Eratosthenes. The original measures were published in my second paper, and it was there stated that the length of the snow was to be multiplied by a constant, unknown at that time. This constant has now been found to be very nearly 2. These measures have recently been repeated and confirmed by Mr. Hamilton. It is therefore determined that the snow does not appear on the summit until colongitude 17°.7, or six hours after the sun first strikes the peak. It does not usually extend beyond the edge of the summit craterlet until colongitude 50°. It then begins to creep over the south-eastern wall, and by 70° has reached a length of about 2″. It begins to shift in azimuth at 60°, and by 130° has changed the azimuth of its major axis from 120° to 150°.

Since the contrast between the white area and its dark background is marked, and the changes in length and azimuth considerable, they are easily seen, so that these observations can be readily repeated by any double-star observer in the north who may be interested or feel skepticism in the matter. Since these changes in size and azimuth are by no means peculiar to Eratosthenes, but may be observed anywhere upon the moon, as has been already shown with regard to the region near Conon, it appears improbable that the whiteness of the lunar summits is due to white quartz or any other variety of white rock. This white area is indicated on the three maps published in connection with my fourth paper by the letter *f*. Should anyone wish to repeat these measures, he may take as fundamental constants the distance *d f* as 4.0 miles, and its azimuth as about 110°. Since the summit *f* is rather difficult to locate within the white area near the time of full moon, it will be more satisfactory to the observer to base his position angles ultimately on the azimuth *a b* which is equal to 116°.3, as described in my second paper on Eratosthenes under Micrometric Measurements. The line joining *a* and *b* is therefore nearly parallel to *d f*.

In this connection it should also be mentioned that the distance between the summits *c* and *f*, owing to the motion of their snow fields, slowly diminishes as the lunation progresses from 2.1 to 1.5 miles, or approximately from 2″ to 1″.4. This fact can also readily be checked in the north with a micrometer. The change appears to be due chiefly to the motion of the snow field about *f*. This fact independently would

seem to cast doubt on the hypothesis that these white areas consist of white rocks.

It may now be well to take up a suggestion that has been made to me by several different astronomers in the endeavor to explain these surface changes, without having recourse to the existence of snow, water vapor, or life on the moon. They understand fully that the dark areas, either fields or plats, cannot be due to shadow, but suggest that, unlike the terrestrial rocks, the surface of the moon is composed largely, in certain selected areas, of dark colored crystals, such as smoky quartz or mica. Where these crystals exist we have the dark areas, since the crystals by specular reflection reflect away most of the rays of the sun. When a dark area is stationary and later disappears, the facets of the crystals must be so turned as to reflect the rays of the sun to us only in certain colongitudes when the disappearance takes place. The number of the facets must then be turned only in such proportions as to make the light just equal to that coming from the immediate surroundings, which are not crystalline, since their light does not vary. When an area shifts, the region in front of it must also be crystalline, with the facets of the crystals so turned as to take up and reflect back to us the proper proportion of light at the proper time.

Now we should remember that this particular arrangement of the crystals must not only take place over areas of several miles in extent, but also that in the case of specular reflection, in order that as seen from most directions a surface should be very dark, nearly all of the light must be sent in some other direction, as in the case of a mirror. In that direction the surface would appear to be extremely brilliant. Hundreds of these variable dark spots are known, even in the comparatively small areas on the moon that have been already explored. There must be many thousands in all, yet not one of them is ever known to become intensely brilliant. Some of them do, as above noted, sooner or later become as bright as their surroundings, and they often thus disappear entirely from view, but the only intensely bright spots are of quite another class. These are the interiors of what we have called the snow craterlets, the interior rims of some of the larger craters, and the mountain summits. On the other hand, except when in shadow, these never become intensely dark. The bright streaks surrounding certain craters are somewhat less brilliant, but these are of an entirely different shape. Furthermore several of these craters like Anaxagoras, Byrgius, and Olbers are found very near the limb of the moon, where it would be impossible for streaks radiating from them in all directions to shine for us by specular reflection. We thus see that specular reflection will explain for us neither the dark spots on the moon, nor the bright shining summits.

We may perhaps be excused if we add still another fact rendering the explanation of specular reflection improbable. In *Harvard Annals* **32**, 92, published in 1895, we find the statement: "The maximum

[darkness] of the Atlas spot, longitude 43° west, is reached three days before the moon is full; the maximum of the spots in Alphonsus, longitude 3° east, is reached one day after it is full; while the maximum of Hansteen, longitude 51° east, is not reached until six and a half days after it is full. It is found, however, that in the case of each of these craters the maximum is reached within less than 48 hours after the sun has passed its meridian, but never earlier. The importance of this fact lies in showing that the darkening depends on the position of the sun relatively to the spot, and has nothing to do with the position of the observer." Hence specular reflection appears improbable.

We will now take up another snow, or perhaps cloud phenomenon, that was strikingly exhibited to us this past December and January. A large shallow crater nearly five miles in diameter is found on the floor of Eratosthenes. It lies to the east of the central peaks, and the southern half of it is indicated on each of the three maps. Its eastern rim is still volcanically active, as is shown by a small snow patch, *v*, which usually lasts through the lunation. From it a brilliant curved rill extends south-easterly to the rim of the great crater. In 1901 the small crater and the floor to the south of it for a distance of eight miles were brilliantly illuminated at colongitude 16°, and also somewhat later, as shown by the photographs in my first paper (POPULAR ASTRONOMY 1919, **27**, 579, Plate 46). With one or two exceptions this phenomenon had not been seen since. Thus in December 1918, colongitude 28°, the brightness of the floor reduced to the present scale was marked 9, in September 1919, colongitude 32°, it was marked 10, and on four other occasions in the same year, prior to colongitude 56°, 8.

What was my surprise this last December at colongitude 28° to see the bright area again appear with a brilliancy 12, the next night 11, and in January, colongitude 22°, 12. Moreover a short rill to the west of the main one, lying along the edge of the floor, which had only occasionally been seen of late years, was now perfectly obvious and distinct. To one familiar with the crater as it had been during the past years, the changed appearance was very striking.

What may perhaps be described as the "prettiest," and possibly the most convincing, view of the little white areas that we attribute to snow, is at the third quarter of the moon, just as the sun is setting on the Apennines. The line of summits shines out sharp and dazzlingly white against the darker valleys and lower slopes. The lunar landscape has a beauty of its own when well seen, that is not unlike the views among the higher mountains of our own planet.

Beyond the whites and grays, the only color that is clearly seen upon the moon is the yellow of the brighter regions. Nevertheless, to a person with a color sensitive eye four other colors may be detected tinting the various grays, but visible only by careful comparison with other grays assumed to be of a neutral tint. One of these is red. This consists of a reddish brown area in the interior of the crater Stevinus,

visible only before the sunlight reaches the bottom of the crater. Both the central peak and its shadow can be certainly distinguished. The illumination however is only faintly marked, but may be detected by comparison with the interior of the crater Snellius situated close beside it. The appearance is quite distinct from, and less visible than the bright reddish boundary of the edge of the crater, due to atmospheric dispersion (*Harvard Annals*, 1895, **32**, 82). Since this spot is visible only between colongitudes 305° and 310°, when the moon will be very low in our temperate zones, it may be described as a difficult object. Northern observers should look for it in May and June, when the new moon is at its highest, and the seeing good.

Near full moon very dark grays, almost blacks, are visible in certain spots within 20° or so of the equator. The best known example of these is Boscovitch, though there are many others. At such times these grays have a distinctly purplish color. It might be well for an observer who has been able to see this color with a refractor, to look for it with a reflector, in order to check the possibility of its being due to the secondary spectrum of the objective. A light violet tinge about Aristarchus is believed to be attributable to this cause. That some grays are browner than others is not a difficult observation, and may be noted in various portions of the disk. A good example near the first quarter of the moon is the brownish color of Mare Frigoris as compared with the neutral gray of Tranquillitatis. The brownish yellow color, as he calls it, of Frigoris is noted by Neison, who also speaks of Palus Somnii, between Tranquillitatis and Crisium, as being of a "peculiar golden brown color."

The greenish color of the central portion of Grimaldi is more difficult to see, but is the best example that we have of this color. Still more difficult is the green in the South-Eastern Field of Eratosthenes. This field is shown on map B of our fourth paper, in latitude 13°.8, longitude 12°.2. The color can most readily be detected by a comparison with the North-Eastern Field shown in Figure 2 of our second paper, and described as the Bird. When the fields are very light, no color can be distinguished. The color appears to be independent of their relative darkness, but before colongitude 50° and after 110° the South-Eastern Field is the browner, and between these colongitudes at the time near full moon, the greener. During this latter period the two fields are about equally dark.

It is believed that the soil of both is darker than the surrounding rocks, and their surfaces smoother. As a result, when the sun first rises on these lighter rocks, the light reflected from them, combined with the lack of light from their absolutely black shadows, will be equal in intensity to the light reflected from the darker fields. The outlines of the latter will therefore be invisible. As the sun rises higher, the shadows disappear, and the surrounding rocks appear lighter, so that the fields become visible as dark areas. Towards sunset the fields

disappear in the same manner. Such changes would be due to the varying brightness of the surroundings, not to the fields themselves. If the fields were only slightly darker than their surroundings, this would fully account for their appearance towards noon, and their disappearance later. No further assumptions would be necessary. Such however is not the case. When the sun is near their meridian they become intensely black. Thus, even as late as 130° we find it stated that "the North Eastern and South Eastern Fields are the same color and darkness, and much darker than the mare to the north." They are therefore far darker than they, or their light surroundings, are early and late in the lunation. To explain this intense darkening, the vegetation hypothesis it is believed is required, as it also is to explain the movements that we observe in the runs and plats. That the fields are nevertheless somewhat darker and smoother than their surroundings is shown by the fact, that when a photograph is taken of them by earthlight, they are seen as comparatively dark areas. Under these conditions vegetation is of course impossible.

Early and Late Seasons on the Moon.

We will now deal with one of those cases where the growth of certain markings is so rapid, that a slight change in lunar physical conditions, in different lunations, produces at identical colongitudes, an appreciable difference in the appearance of the spots. The region that we shall select to study lies directly east of Laurel Plat, number 36 on our maps. When first uncovered by the shadow, at colongitude 15°, the plat is entirely disconnected from the regions to the east of it, but later it extends a run connecting it with Main, and a day later this run crosses Main, and reaches the western side of the great South-Eastern Field, that is in the meantime slowly advancing over the crater rim, and down the interior wall to meet it. The portion of the run between Laurel and Main we shall call Laurel Run West, and the part to the east of Main, Laurel Run East.

Observations of this region have now been carried out through thirty different lunations, beginning in 1904 at the Lowe Observatory in California, with a 16-inch refractor. The later lunations were observed here. The first column of Table I gives the number of the lunation, the second the colongitude at which the drawing was made, the third the date, the fourth the seeing on the Lunar Scale, which is intended to coincide with the Standard, and the fifth and sixth the width of the Western and Eastern runs in miles, as measured on the drawings. A zero in these last two columns indicates that the run was not visible.

TABLE I.

LAUREL RUN.

Lunation	Colong.	Date	Seeing	W	E
	°				
8	36	'18 Nov. 13	8	0.3	0
11	37	'19 Jun. 8	8	0	0
6	37	'18 Sep. 15	—	0.2	0
15	38	'19 Oct. 4	7, 8	0	0
27	39	'23 Sep. 20	8, 10	0.2	0
9	41	'18 Dec. 13	9	0	0
18	41	'20 Jan. 1	10	0	0
3	42	'12 Jul. 24	7	1.0	0
5	43	'18 Aug. 17	10	0	0
7	43	'18 Oct. 15	8	0	0
26	44	'23 Aug. 22	—	1.0	0
16	44	'19 Nov. 3	10	0	0
2	46	'12 Jun. 25	—	0	0
8	48	'18 Nov. 14	10	0.6	0
24	49	'22 Oct. 31	10	0	0
11	49	'19 Jun. 9	10	0	0
25	50	'23 Jul. 24	7, 10	0.5	0
3	53	'12 Jul. 25	6, 9	0.7	0
9	53	'18 Dec. 14	10	0	0
7	55	'18 Oct. 16	8	0	0
16	56	'19 Nov. 4	10	0	0
12	56	'19 Jul. 9	9, 8	0.7	0
5	56	'18 Aug. 18	9	0	0
14	56	'19 Sep. 6	—	0	0
26	57	'23 Aug. 23	8, 11	0.7	0
2	59	'12 Jun. 26	—	3.5	2.8
4	60	'12 Aug. 24	—	4.0	4.5
6	61	'18 Sep. 17	8, 9	0.5	0
8	61	'18 Nov. 15	8	0.5	0
1	61	'04 Jul. 24	6, 5	0	0
10	61	'19 Apr. 12	10	4.7	3.8
25	62	'23 Jul. 25	9, 12	0.4	0
13	62	'19 Aug. 8	9	0	0
27	63	'23 Sep. 22	6, 8	0	0
20	63	'20 Oct. 24	8	0.6	0
15	64	'19 Oct. 6	—	0.3	0
23	67	'21 Jan. 21	8	1.5	1.5
7	67	'18 Oct. 17	8	0	0
5	68	'18 Aug. 19	10	0	0
12	68	'19 Jul. 10	9, 8	0	0
21	68	'20 Nov. 23	—	0.5	0
26	69	'23 Aug. 24	9, 10	0.8	0
14	69	'19 Sep. 7	11	0.6	0.6
2	71	'12 Jun. 27	—	3.0	3.8
1	72	'04 Jul. 25	6	0	0
28	74	'23 Nov. 21	8, 5	0.3	0.5
10	74	'19 Apr. 13	8	2.3	2.5
25	74	'23 Jul. 26	8, 10	0	0
6	74	'18 Sep. 18	9	0.9	0.6
22	74	'20 Dec. 23	11	0.7	0
15	75	'19 Oct. 7	11	0	0
19	77	'20 Aug. 27	11	0.3	0.3
20	77	'20 Oct. 25	—	0.5	0
18	77	'20 Jan. 4	9	0.3	0
23	79	'21 Jan. 22	10	1.0	1.3
14	81	'19 Sep. 8	9	0.8	0.8
16	81	'19 Nov. 6	12	1.5	1.5
21	81	'20 Nov. 24	10	0.5	2.0
12	82	'19 Jul. 11	8, 9	0	0

TABLE I—(Continued).

Lunation	Colong.	Date			Seeing	W	E
	°						
2	83	'12	Jun.	28	—	2.5	2.5
30	84	'24	Jan.	20	11, 12	1.6	1.8
1	84	'04	Jul.	26	7, 6	3.0	3.0
28	85	'23	Nov.	22	9, 6	0.6	0.8
10	86	'19	Apr.	14	8	4.0	6.0
25	87	'23	Jul.	27	10	2.0	1.4
22	87	'20	Dec.	24	10	1.2	1.6
27	87	'23	Sep.	24	9, 12	3.5	3.8
13	88	'19	Aug.	10	9	2.8	2.9
20	89	'20	Oct.	26	11	1.5	1.3
23	90	'21	Jan.	23	9	2.6	2.6
29	91	'23	Dec.	22	—	2.2	2.5
7	92	'18	Oct.	19	9	2.0	2.5
16	92	'19	Nov.	7	10	2.6	2.2
12	94	'19	Jul.	12	8, 9	2.6	2.6
30	96	'24	Jan.	21	8	2.0	2.2
1	97	'04	Jul.	27	7	5.1	4.3
15	99	'19	Oct.	9	11	3.5	3.3
28	99	'23	Nov.	23	—	2.2	2.6
27	100	'23	Sep.	25	10	3.4	3.8
29	103	'23	Dec.	23	9, 10	2.3	0.7
12	105	'19	Jul.	13	7	4.0	5.5
16	105	'19	Nov.	8	11	3.6	4.0
21	106	'20	Nov.	26	—	3.0	3.3
2	108	'12	Jun.	30	—	4.0	5.7
30	109	'24	Jan.	22	7, 9	2.5	2.5
1	110	'04	Jul.	28	7, 8	3.7	5.2
17	111	'19	Dec.	8	11	2.5	6.2
25	112	'23	Jul.	29	10, 11	4.0	2.5
13	112	'19	Aug.	12	8	4.5	4.0
9	115	'18	Dec.	19	7, 8	3.0	4.0
7	117	'18	Oct.	21	9	5.7	3.0
12	120	'19	Jul.	14	10	5.3	5.1
30	121	'24	Jan.	23	9, 11	3.0	2.5
1	122	'04	Jul.	29	7, 8	3.7	5.6
15	124	'19	Oct.	11	10	3.0	3.5
25	125	'23	Jul.	30	12, 9	5.8	6.5
13	125	'19	Aug.	13	9	4.7	4.4
9	128	'18	Dec.	20	6, 5	3.0	3.7
7	130	'18	Oct.	22	10	3.7	4.5

The eastern run was seen in 23 of these lunations, the earliest colongitude at which it was recorded being 59°, and the two latest times of its first appearance 111° and 115°. Both of these figures however were due to the lack of earlier observations at suitable colongitudes. At every first appearance after colongitude 90° its breadth was already 2.5 miles or over, so we may consider that it would have been seen earlier at each of these lunations had circumstances been more favorable. On the other hand several times at 87° and 89° the width was only about 1.5 miles, which implies that these really were first appearances, so that we may say that the eastern run when seen under favorable circumstances, nearly always appears for the first time between 60° and 90°. Fifty-three per cent of the 17 accepted first appearances lie between 80° and 90°, and the other half of them before 80°.

The western run, which appeared in 28 lunations, is subject to much

wider fluctuations. Its earliest appearance is recorded at 20°, and three times it is drawn prior to 30°. On the other hand at each of the four first appearances after 85° it was at least 2.0 miles in width, while earlier first appearances were usually narrow, so that we may exclude these four cases as being only apparent, and due to lack of earlier satisfactory observations. In the remaining 24 lunations in twenty-five per cent of the observations, the first appearance occurred between colongitudes 60° and 70°. Half of the first appearances occurred before 61°. The extreme range of colongitude of the accepted first appearances of this run extend therefore from 20° to 85°, or through 65°, giving a range of a little over five terrestrial days in the time of its

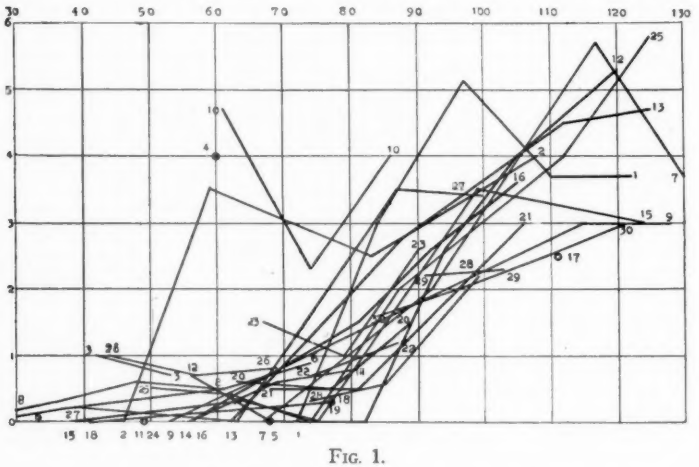


FIG. 1.

appearance. With a total duration of sunlight of only fifteen days, this is certainly a remarkable percentage. The results of our measures for the western run after colongitude 30° are plotted in Figure 1, where the abscissas represent colongitudes, taken from the second column of the table, and the ordinates widths taken from the fifth. Of the various early observations in which the run was not visible, only the last one is plotted in the figure. The numbers refer to the different lunations.

The run increases in width most rapidly, as shown by Figure 1, between colongitudes 75° and 95°, or just before full moon, and reaches its maximum width at about 120°. The maximum rate of increase is 2.5 miles in 20° of colongitude, or 13800 feet in 2357 minutes. This is practically at a speed of 6 feet per minute, or 3 centimeters per second, which is by far the most rapid motion that we have yet detected upon the moon, 2 feet per minute being the previous maximum. After colongitude 130° the run always becomes irregular in detail, breaks up,

and fades out. By 178° the shadow of the eastern wall of the crater invades the region, and soon all is involved in universal blackness. It is odd that the run should seem to know that the sunlight will be withdrawn just four days later. The run may arrive early or late, but it always disappears exactly on time. Altitude of the sun at disappearance 60°.

Another curious fact that we may derive from the figure is that among those drawings where the run is actually visible, as for instance in colongitude 85°, we find a range of width extending from 0.6 to 3.8 miles. Omitting the last as possibly erroneous, we find two drawings giving it a width of 3.2 miles. These differences we believe to be real, since an error of such size would be impossible in a series of careful drawings of lunar detail. We find therefore that at the same colongitude a more rapid development or growth has occurred during some lunations than during others.

We also find that an early rapid development will generally retain its lead, when the drawings are all made on successive nights. This confirms us in the belief that the difference in breadth recorded in different lunations is real, for if imaginary, or incorrectly drawn, the lines would constantly cross one another about the mean location of the curve. Comparing lunations 1, 13, 16, 7, 25, 21, and 28, in the figure, at colongitude 80°, we find that in each one the run is a little narrower than in its predecessor. At 100°, or nearly two days later, the same sequence is retained. If the lunation is a favorable one to vegetation, and the run gets a good start, it will continue to remain wider in the favorable than in less favorable lunations.

The lunar atmosphere is so rare, that it does not seem possible that there can be weather on the moon, in the sense that we have it here, although the larger clouds, as we shall show in another paper, do shift their places somewhat, and the smaller ones, which we call cloudlets, occur sometimes in one place, and sometimes in another at the same colongitude. Practically all the moisture on the moon comes we believe from its interior. While we believe that the changes that we observe in the fields, plats, and runs are due mainly to the growth and development of vegetation, we must nevertheless not neglect the fact that some of these changes may also be in part due to shifting clouds. Thus during lunation number 9, Laurel West appeared in colongitude 28° with a width of 0.5 miles, but disappeared again, and was not detected at either 41° or 53°. In lunation 11 it appeared at 25°, but was invisible at 37° and 49°. Similarly in lunation 12 it appeared at 56°, disappeared in 68° and 82°, but reappeared at 94°. Lunations 14, 25, and 27 presented similar phenomena. That these disappearances can hardly be due to bad seeing is indicated by the fourth column of the table. While in some of the above cases it is possible that the run was overlooked, when it should have been seen, it does not seem likely that this was usually so.

It may appear to some of my readers that when we observe actual motions occurring on the face of the moon, that if these are not ascribed to clouds, they should be explained by animal rather than by vegetable life. When the dark body actually moves over or across the surface, this may perhaps be so, but here we have instead, a case of growth rather than actual translation. Where growth depends on temperature, as is the case in most parts of our earth outside of the tropics, vegetation develops in large areas all at once, but where growth depends on moisture, as for instance in the Nile valley, and on the moon, and Mars, we may have a progressive growth, dependent on the speed of transference of the fertilizing moisture. We believe that we have here such a phenomenon in the case of Laurel West and East Runs.

Mandeville, Jamaica, B. W. I., February 11, 1924.

INFINITY.

Amidst a system of star spheres,
  Which whirl around a Sun,
Man makes his home a few brief years,
  Until his work is done.

Upon a tiny planet and
  Within the Milky Way,
Mid magnitudes that God hath planned
  And laws which worlds obey.

In gulf-like depth whence flows its light,
  There beams a brilliant star,
And others shine in skies at night
  A thousand times as far.

And modern science has revealed
  Suns too remote to see,
Yet countless stars remain concealed
  Throughout Infinity.

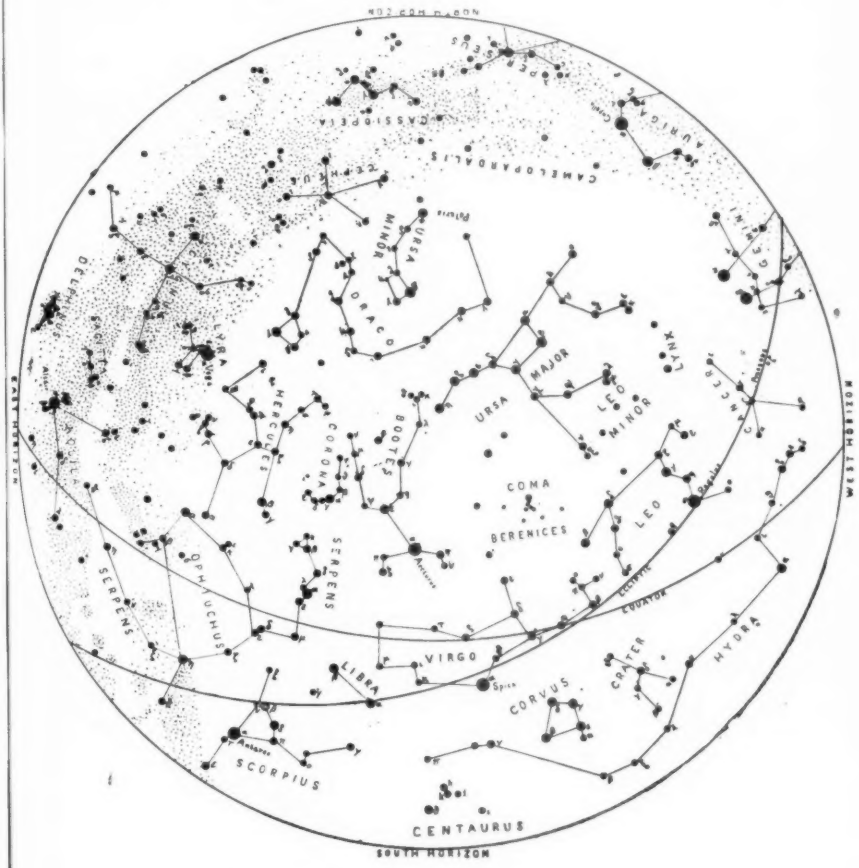
Around us, lies abysmal space,
  A space without an end,
Which He that wrought our human race,
  Alone can comprehend.

CHARLES NEVERS HOLMES.

41 Arlington St., Newton, Mass.

PLANET NOTES FOR JUNE.

The *Sun* will move northeastward from $4^h\ 36^m$, $+22°\ 3'$ at the beginning of the month to $5^h\ 59^m$, $+23°\ 27'$ on June 21. For the rest of the month it will begin its motion southward slowly and by the end of the month will be at $6^h\ 37^m$, $+23°\ 11'$. The time on June 21 when the sun reaches its farthest posi-



THE CONSTELLATIONS AT 9:00 P. M. JUNE 1.

tion north is the time of the summer solstice, and is the time stated in the almanac as the beginning of summer. On this date the sun will be above the horizon longer than on the preceding days or the following days, and it is therefore the longest day of the year. The difference in length between the day immediately preceding and the one immediately following is slight, and could be

noted only by careful observations. The sun will move from the constellation Taurus into the constellation Gemini.

The phases of the *Moon* will occur as follows:

New Moon	June	2	at 9 A.M.	C.S.T.
First Quarter		10	" 8 A.M.	"
Full Moon		16	" 11 P.M.	"
Last Quarter		23	" 8 P.M.	"

The *Moon* will be farthest from the earth twice during the month, on June 1 and on June 29. It will be nearest the earth on June 16.

Mercury will reach a point of greatest elongation west of the sun on June 3. On and near this date it will rise about one hour and a half before the sun, and hence will be a morning star at this time. With a little care in noting its position from morning to morning it will perhaps be possible to see this planet until the twentieth of the month. After that it will be quite near the sun. It will pass the sun from west to east early in July.

Venus will be low in the west at sunset at the beginning of the month. It may be visible until the middle of the month but it will be too low in the west for any good observations. It will pass the sun on the earthward side on July 1.

Mars will be in good position for early morning observations. It will cross the meridian about four o'clock in the morning.

Jupiter at the middle of the month will cross the meridian about eleven o'clock. It therefore, except for the fact that it will be quite far south, will be very favorably situated.

Saturn will be some distance northwest of Jupiter. On June 15 it will cross the meridian at 8:04. This will therefore perhaps be the most interesting object for the visitors to the observatories during the month.

Uranus will be in quadrature, 90° west of the sun on June 12. On this date it will be on the meridian at sunrise.

Neptune will be in the western sky at sunset throughout the month.

Phenomena of Jupiter's Satellites.

VISIBLE AT WASHINGTON.

[From the *American Ephemeris.*]

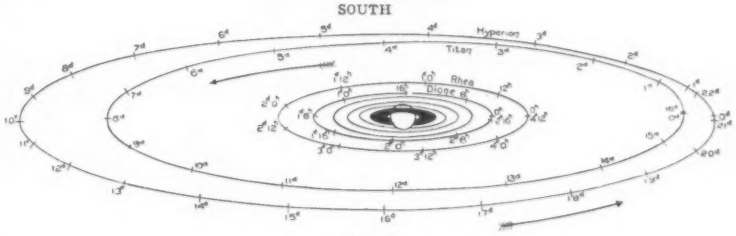
CENTRAL STANDARD TIME, NOON = 0^h

1924	h	m			1924	h	m		
June 1	8	49	II	Oc. R.	June 10	8	21	I	Oc. D.
	12	5.9	I	Ec. D.		10	39.8	I	Ec. R.
	14	22	I	Oc. R.	11	7	41	I	Tr. E.
2	9	15	I	Sh. I.		7	50	I	Sh. E.
	9	20	I	Tr. I.	13	7	36	III	Oc. D.
	11	27	I	Sh. E.		10	45.2	III	Ec. R.
	11	31	I	Tr. E.	15	10	58	II	Oc. D.
	14	9	III	Sh. I.		13	52.1	II	Ec. R.
	14	30	III	Tr. I.	16	12	48	I	Tr. I.
3	8	48	I	Oc. R.		13	4	I	Sh. I.
6	14	29	II	Tr. I.	17	8	11	II	Tr. E.
	14	31	II	Sh. I.		8	47	II	Sh. E.
8	8	42	II	Oc. D.		10	5	I	Oc. D.
	11	15.2	II	Ec. R.		12	33.9	I	Ec. R.
	13	55	I	Oc. D.	18	7	14	I	Tr. I.
9	11	4	I	Tr. I.		7	33	I	Sh. I.
	11	10	I	Sh. I.		9	25	I	Tr. E.
	13	15	I	Tr. E.		9	45	I	Sh. E.
	13	22	I	Sh. E.	20	10	53	III	Oc. D.

1924	h	m			1924	h	m		
June 22	13	14	II	Oc. D.	June 25	8	59	I	Tr. I.
24	8	5	II	Tr. I.		9	27	I	Sh. I.
	8	57	II	Sh. I.		11	10	I	Tr. E.
	10	26	II	Tr. E.		11	39	I	Sh. E.
	11	21	II	Sh. E.	26	8	56.6	I	Ec. R.
	11	50	I	Oc. D.					

NOTE:—I, denotes ingress; E, egress; D, disappearance; R, reappearance; Ec, eclipse; Oc, occultation; Tr, Transit of the satellite; Sh, transit of the shadow.

Saturn's Satellites.



Apparent orbits of the seven inner satellites of Saturn at date of opposition, April 18, 1924, as seen in an inverting telescope.

[From the *American Ephemeris.*]

CENTRAL STANDARD TIME, NOON = 0^h

I. Mimas. Perod 0^d $22^h.6$.

1924	d	h		d	h		d	h		d	h	
June	1	8.2	E	June 8	10.0	W	June 16	10.1	E	June 23	11.8	W
	2	6.9	E	9	8.6	W	17	8.7	E	24	10.4	W
	4	15.4	W	10	7.2	W	18	7.4	E	25	9.0	W
	5	14.0	W	13	14.3	E	21	14.5	W	26	7.6	W
	6	12.7	W	14	12.9	E	22	13.2	W	30	13.4	E
	7	11.3	W	15	11.5	E						

II. Enceladus. Period 1^d $8^h.9$.

June	1	22.9	E	June 10	4.2	E	June 18	9.4	E	June 25	5.9	E
	3	7.7	E	11	13.0	E	19	18.3	E	26	14.7	E
	4	16.6	E	12	21.9	E	21	3.2	E	27	23.6	E
	6	1.5	E	14	6.8	E	22	12.1	E	29	8.5	E
	7	10.4	E	15	15.7	E	23	21.0	E	30	17.4	E
	8	19.3	E	17	0.6	E						

III. Tethys. Period 1^d $21^h.3$.

June	2	8.5	E	June 9	21.7	E	June 17	10.9	E	June 25	0.2	E
	4	5.8	E	11	19.0	E	19	8.2	E	26	21.5	E
	6	3.1	E	13	16.3	E	21	5.5	E	28	18.8	E
	8	0.4	E	15	13.6	E	23	2.8	E	30	16.1	E

IV. Dione. Period 2^d $17^h.7$.

June	3	4.5	E	June 11	9.5	E	June 19	14.5	E	June 27	19.6	E
	5	22.1	E	14	3.1	E	22	8.2	E	30	13.3	E
	8	15.8	E	16	20.8	E	25	1.9	E			

V. Rhea. Period 4^d $12^h.5$.

June	2	18.3	E	June 11	19.1	E	June 20	19.9	E	June 29	20.7	E
	7	6.7	E	16	7.5	E	25	8.3	E			

VI. Titan. Period 15^d $23^h.3$.

June	5	5.8	W	June 13	5.0	E	June 21	4.2	W	June 29	3.5	E

VII. Hyperion. Period 21^d $7^h.6$

June	4	13.2	E	June 14	7.0	W	June 25	18.4	E

NOTE—E, Eastern Elongation; W, Western Elongation.

Occultations Visible at Washington.

[*From the American Ephemeris*]

Date 1924	Star's Name	Magnitude	IMMERSION. Washington M.T.	IMMERSION. Angle from N	EMERSION. Washington M.T.	EMERSION. Angle from N	Duration
			h m	°	h m	°	h m
June 11	γ Virginis	2.9	6 26	155	7 31	263	1 5
14	γ Librae	4.0	8 34	96	9 48	307	1 14
14	η Librae	5.5	13 42	147	14 27	235	0 45
17	29 Sagittarii	5.3	9 56	114	11 3	255	1 8
18	57 Sagittarii	6.0	9 37	49	10 26	310	0 49
20	μ Capricorni	5.2	11 24	35	12 12	301	0 49
28	70 Tauri	6.4	14 37	65	15 31	265	0 54
28	α Tauri (*Ald.*)	1.1	20 30	110	21 43	215	1 13

COMET AND ASTEROID NOTES.

New Comet *a* 1924 (Reid).— A cablegram from Copenhagen to Harvard College Observatory on April 4 announces the discovery of a comet by Reid, of Cape Town, on March 30. The position given is as follows:

1924 March 30 $6^h\,07^m.7$ G. M. T. $\alpha\ 2^h\,58^m\,19^s.8$; $\delta\ -33°\,38'\,16''$.

The daily motion is given as $+3^m\,32^s$, $+30'$. The brightness of the comet is not stated.

The following preliminary elements have been computed at the Cape Observatory:

$$\left.\begin{aligned} T &= 1924\ \text{Feb.}\ 22.78\ \text{G. M. T.} \\ \omega &= 260°\ 40' \\ \Omega &= 111\ \ 18 \\ i &= \ \ 72\ \ 22 \end{aligned}\right\} 1924.0$$
$$\log q = 0.23350$$

In the Copenhagen Circular No. 39 is given the following ephemeris, computed from the above elements by Messrs. Jens Johannsen and Bengt Strömgren of the Copenhagen Observatory. This ephemeris shows that the comet is coming north and may possibly be detected by northern observers in May, although it will be too much involved in the evening twilight for satisfactory study.

1924		α 1924.0	δ 1924.0	log r	log Δ
		12^h Gr. M. T.			
		h m s	° ′		
April	6	3 23 43	—29 27	0.2565	0.3590
	10	36 19	27 26		
	14	48 23	25 26	0.2649	0.3708
	18	3 59 57	23 30		
	22	4 11 3	21 37	0.2743	0.3847
	26	21 42	19 49		
	30	31 56	18 5	0.2845	0.4002
May	4	41 47	16 25		
	8	4 51 17	14 49	0.2954	0.4164
	12	5 0 28	13 18		
	16	9 21	11 52	0.3067	0.4330
	20	17 56	10 31		
	24	26 15	9 15	0.3184	0.4493
	28	34 18	8 4		
June	1	5 42 8	— 6 56	0.3304	0.4651

VARIABLE STARS.

Minima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1924 June					
	h m	° ′		d h	d h	d h	d h	d h	d h	d h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8	3 8					
RT Sculptor.	31.5	—26 13	9.6—10.5	0 12.3	5 6	12 23	20 15	28 7		
U Cephei	0 52.4	+81 20	7.0— 9.0	1 11.8	1 1	7 12	15 0	22 12		
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	1 2	7 4	19 10	25 12		
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	4 12	13 2	21 16	30 6		
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	1 20	7 17	22 10	29 7		
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	4 6	11 10	18 15	25 18		
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2		9 13	18 8	27 3		
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	8 22	16 20	24 19			
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6	4 21					
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	4 15	13 5	21 20	30 10		
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	6 12	13 7	20 2	26 21		
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	4 21	12 19	20 16	28 14		
RW Tauri	3 57.8	+27 51	7.1— [11	2 18.5	9 5	17 13	25 20			
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	5 4	13 2	20 23	28 21		
RW Persei	13.3	+42 04	8.8—11.0	13 04.8	1 4	14 9	27 14			
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	4 0	10 7	22 22	29 5		
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	9 20		22 6			
TT Aurigae	5 02.8	+39 27	7.8— 8.7	0 16.0	2 15	9 7	22 15	29 7		
RY Aurigae	11.5	+38 13	10.7—11.7	2 17.5	8 21	17 1	25 5			
RZ Aurigae	42.9	+31 40	10.6—13.3	3 00.3	1 3	7 4	19 5	25 5		
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	7 13	16 5	24 21			
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	4 19	15 4	25 14			
SV Gemin.	54.6	+24 28	9.8— [11	4 00.2	5 10	13 10	21 11	29 11		
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	5 0	10 17	22 4	27 22		
U Columbæ	6 11.2	—33 03	9.2—10.0	2 19.2	2 0	13 5	18 19	30 0		
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	4 6	12 11	20 16	28 20		
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	3 7	10 22	18 13	26 4		
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	3 1	15 6	27 11			
RU Monoc.	6 49.4	— 7 28	9.8—10.5	0 21.5	1 16	8 20	23 4	30 9		
R Can. Maj.	7 14.9	—16 12	5.8— 6.4	1 03.3	6 14	13 9	20 5	27 1		
RY Gemin.	21.7	+15 52	8.9— [10	9 07.2	2 18	12 1	21 8	30 15		
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	5 7	11 22	18 13	25 3		
TX Gemin.	30.3	+17 08	10.0—11.9	2 19.2	2 8	10 10	19 3	27 12		
RR Puppis	43.5	—41 08	9.4—10.7	6 10.3	3 1	9 11	22 8	28 18		
V Puppis	7 55.4	—48 58	4.1— 4.8	1 10.9	7 10	14 17	21 23	29 6		
X Carinae	8 29.1	—58 53	7.9— 8.7	0 13.0	7 18	15 21	24 0			
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	6 20	16 8	25 19			
RX Hydrae	9 00.8	— 7 52	9.1—10.5	2 06.8	3 6	10 2	23 19	30 15		
S Velorum	29.4	—44 46	7.8— 9.3	5 22.4	2 8	8 6	20 3	26 1		
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	5 7	12 0	18 18	25 12		
RR Velorum	10 17.8	—41 36	10.0—10.9	1 20.5	3 3	10 13	17 23	25 9		
SS Carinæ	10 54.2	—61 23	12.2—12.8	3 07.2	6 23	13 14	20 4	26 19		
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	3 5	12 0	20 19	29 14		
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	4 10	11 18	19 22	26 10		
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	3 11	10 6	23 20	30 15		
RZ Centauri	12 55.6	—64 05	8.5— 8.9	1 21.0	1 6	8 18	16 6	23 18		
RS Can. Ven	13 06.3	+36 28	7.5—12.5	4 19.1	7 0	16 15	26 0			
SS Centauri	07.2	—63 37	8.8—10.4	2 11.3	3 15	11 1	18 12	25 23		
SX Hydræ	13 39.0	—26 23	8.6—12.7	2 21.5	4 3	9 22	21 12	27 7		

Minima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1924 June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
δ Libræ	14 55.6	— 8 07	4.8— 6.2	2 07.9	4 13	11 12	18 12	25 11				
U Coronæ	15 14.1	+32 01	7.6— 8.7	3 10.9	5 10	12 8	19 5	26 3				
TW Draconis	15 32.4	+64 14	7.3— 8.9	2 19.4	7 4	15 14	24 0					
SS Libræ	15 43.4	—15 14	9.3—11.5	0 18.4	2 18	9 22	17 3	24 9				
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	1 9	8 17	23 9	30 17				
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5	4 9	12 15	20 21	29 3				
R Aræ	31.1	—56 48	6.8— 7.9	4 10.2	9 7	18 4	27 0					
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	7 19		27 13					
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	7 19	13 15	20 10	27 5				
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	4 1	12 10	20 19	29 5				
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	1 12	7 16	19 22	26 3				
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	2 17	8 22	21 6	27 11				
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	1 9	8 18	23 12	30 21				
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	7 18	15 23	24 3					
TX Scorpii	48.6	—34 13	7.5— 8.2	0 22.6	8 11	16 0	23 13					
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	3 16	11 10	19 3	26 21				
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	5 18	13 18	21 17	29 17				
WX Sagittarii	53.6	—17 24	9.2—10 8	2 03.1	4 16	13 4	21 16	30 5				
WY Sagittarii	17 54.9	—23 01	9.5—10.6	4 16.0	5 1	14 9	19 1	28 9				
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	3 14	13 22	19 2	29 11				
RS Sagittarii	11.0	—34 08	5.9— 6.3	2 10.0	4 21	12 3	19 9	26 15				
V Serpentis	11.1	—15 34	9.5—11.1	3 10.9	3 22	10 20	17 18	24 15				
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2		15 0		30 4				
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	5 19	12 23	20 3	27 7				
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	4 9	11 12	18 15	25 17				
SX Sagittarii	39.7	—30 36	8.7— 9.8	2 01.8	1 6	9 13	17 21	26 4				
RR Draconis	40.8	+62 34	9.3—13	2 19.9	3 5	11 17	20 5	28 17				
RS Scuti	43.7	—10 21	9.3—10.3	0 15.9	4 10	11 2	17 17	24 9				
β Lyræ	46.4	+33 15	3.4— 4.1	12 21.8	4 23	17 20	30 18					
U.Scuti	18 48.9	—12 44	9.1— 9.6	0 22.9	5 17	13 9	21 0	28 16				
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	6 0	13 14	21 3	28 17				
RV Lyræ	12.5	+32 15	11. —12.8	3 14.4	6 5	13 10	20 15	27 19				
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	5 14	14 13	23 12					
U Sagittæ	14.4	+19 26	6.5— 9.0	3 09.1	5 8	12 2	18 20	25 15				
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	1 23	9 8	16 17	24 1				
TT Lyræ	24.3	+41 30	9.4—11.6	5 05.8	1 13	12 1	17 6	27 18				
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	7 10	13 22	20 11	26 23				
SY Cygni	19 42.7	+32 28	10. —12	6 00.2	4 6	10 6	22 6	28 7				
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	1 13	8 4	21 11	28 2				
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	4 21	14 0	18 14	27 17				
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	7 8	15 19	24 5					
RW Capric.	12.2	—17 59	8.8—10.6	3 09.4	7 18	14 13	21 8	28 3				
UW Cygni	19.6	+42 55	10.5—13	3 10.8	4 10	11 7	18 5	25 3				
V Vulpec	32.3	+26 15	8.2— 9.8	37 19.0								
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	3 21	13 12	23 2					
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	9 15	18 20	28 1					
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	6 15	15 14	24 14					
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	6 17	14 8	21 22	29 12				
RR Vulpec	20 50.5	+27 32	9.6—11.0	5 01.2	2 19	12 21	23 0					
RY Aquarii	21 14.8	—11 14	8.8—10.4	1 23.2	5 3	13 0	20 21	28 18				
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3	8 16							
RT Lacertæ	21 57.4	+43 24	9.1—10.5	5 01.7	2 2	12 5	22 9					
RW Lacertæ	22 40.6	+49 08	10.2—11.2	5 04.4	3 19	14 4	19 8	29 17				
VW Pegasi	51.7	+32 42	10.0—10.6	5 06.4	5 4	10 10	20 23	26 5				
Y Piscium	23 29.3	+ 7 22	9.0—12.0	3 18.4	3 3	10 16	18 5	25 18				
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	6 12	14 18	23 0					

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5h; Central Standard time 6h. etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1924							
					June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7	9 1							
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 01.7	7 19	15 23	24 2					
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	4 23	12 17	20 11	28 4				
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2	7 12		22 7					
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5 3	13 2	21 0	28 23				
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	5 17	13 12	21 7	29 2				
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	5 13		21 23					
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	8 23	17 13	26 3					
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	3 9	14 12	25 15					
RX Aurigæ	4 54.5	+39 49	7.2— 8.1	11 15.0	5 16	17 7	28 22					
SX Aurigæ	5 04.6	+42 02	8.0— 8.7	1 12.8	5 13	13 5	20 21	28 13				
SY Aurigæ	05.5	+42 41	8.4— 9.5	10 03.3	9 3	19 6	29 10					
Y Aurigæ	21.5	+42 21	8.6— 9.6	3 20.6	5 5	13 22	20 15	28 9				
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	5 7	10 19	21 21	27 9				
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	4 23	12 13	20 2	27 16				
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3		12 12						
RT Aurigæ	23.0	+30 33	5.1— 6.0	3 17.5	6 15	14 2	21 12	29 0				
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	8 1	15 23	23 21					
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	2 20	13 0	23 4					
RU Camelop	7 10.9	+69 51	8.5— 9.8	22 06.5	7 16			29 23				
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	5 16	13 15	21 14	29 12				
V Carinae	8 26.7	—59 47	7.4— 8.1	6 16.7	7 16	14 8	21 1	27 17				
T Velorum	8 34.4	—47 01	7.6— 8.5	4 15.3	2 8	11 14	20 21	30 4				
V Velorum	9 19.2	—55 32	7.5— 8.2	4 08.9	1 6	10 1	18 18	27 '				
Z Leonis	9 46.4	+27 22	7.9— 9.6	56 08.7								
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	7 14	14 9	21 4	27 23				
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	4 12	11 3	24 8	30 23				
S Muscae	12 07.4	—69 36	6.4— 7.3	9 15.8	5 14	15 6	24 22					
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	3 10	11 9	19 8	27 8				
T Crucis	15.9	—61 44	6.8— 7.6	6 17.6	4 18	11 11	18 5	24 23				
R Crucis	18.1	—61 04	6.8— 7.9	5 19.8	2 10	8 6	19 21	25 17				
S Crucis	12 48.4	—57 53	6.5— 7.6	4 16.6	5 10	14 18	19 11	28 20				
W Virginis	13 20.9	— 2 52	8.7—10.4	17 06.5		14 17						
SS Hydræ	25.0	—23 08	7.4— 8.1	8 04.8	1 19	10 0	18 5	26 10				
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	4 12	11 13	18 13	25 14				
ST Virginis	14 22.5	— 0 27	10.3—11.4	0 09.9	1 11	9 17	17 22	26 4				
V Centauri	25.4	—56 27	6.4— 7.8	5 11.9	5 4	10 16	21 16	27 4				
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	4 16	12 5	19 18	27 7				
R Triang.Austr.	15 10.8	—66 08	6.7— 7.4	3 09.3	5 6	12 1	18 20	25 14				
S Triang.Austr.	15 52.2	—63 29	6.4— 7.4	6 07.8	2 0	8 7	20 23	27 7				
S Normæ	16 10.6	—57 39	6.6— 7.6	9 18.1	6 6	16 0	25 18					
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	8 1	16 22	25 18					
RV Scorpii	16 51.8	—33 27	6.7— 7.4	6 01.5	6 13	12 14	24 17	30 19				
X Sagittarii	17 41.3	—27 48	4.4— 5.0	7 00.3	2 0	9 0	24 0	30 1				
Y Ophiuchi	47.3	— 6 07	6.1— 6.5	17 02.9		11 19		28 22				
W Sagittarii	17 58.6	—29 35	4.3— 5.1	7 14.3	2 16	10 6	17 20	25 11				
Y Sagittarii	18 15.5	—18 54	5.4— 6.2	5 18.6	1 21	13 11	19 5	30 18				
U Sagittarii	26.0	—19 12	6.5— 7.3	6 17.9	2 11	9 4	22 16	29 10				
Y Scuti	32.6	— 8 27	8.7— 9.2	10 08.3	6 0	16 8	26 17					
RZ Lyræ	39.9	+32 42	9.9—11.2	0 12.3	4 8	10 11	22 18	28 21				
RT Scuti	18 44.1	—10 30	9.1— 9.7	0 11.9	1 11	7 10	19 7	25 6				
κ Pavonis	18 46.6	—67 22	3.8— 5.2	9 02.2	2 6	11 8	20 11	29 13				
U Aquilæ	'9 24.0	— 7 15	6.2— 6.9	7 00.6	7 3	14 4	21 4	28 5				
XZ Cygni	19 30.4	+56 10	8.6— 9.3	0 11.2	1 18	8 19	22 19	29 19				

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1924							
					June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	6 21	14 20	22 20	30 19				
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	2 21	10 14	18 6	25 23				
η Aquilæ	47.4	+ 0 45	3.7— 4.5	7 04.2	4 7	11 11	18 15	26 20				
S Sagittæ	51.5	+16 22	5.6— 6.4	8 09.2	7 10	15 19	24 4					
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	4 1	10 8	23 0	29 7				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	1 2		17 11					
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	3 17	12 14	17 1	25 21				
UY Cygni	52.3	+30 03	9.6—10.4	0 13.5	3 23	10 16	24 3	30 21				
RV Capric.	55.9	—15 37	9.2—10.1	0 10.7	3 12	10 5	23 15	30 9				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	1 22		16 15					
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	2 10	10 7	18 3	26 0				
SW Aquarii	10.2	— 0 20	9.9—10.8	0 11.0	2 10	9 8	23 2	30 0				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	2 11	12 4	17 1	26 18				
Y Lacertæ	22 05.2	+50 33	9.1— 9.6	4 07.8	2 12	11 3	19 19	28 11				
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	5 9	10 17	21 11	26 20				
Z Lacertæ	36.9	+56 18	8.2— 9.0	10 21.1	5 19	16 17	27 14					
RR Lacertæ	37.5	+55 55	8.5— 9.2	6 10.1	4 23	11 8	24 4	30 14				
V Lacertæ	44.5	+55 48	8.5— 9.5	4 23.6	5 11	15 10	20 10	30 9				
X Lacertæ	22 45.0	+55 54	8.2— 8.6	5 10.7	5 18	11 5	22 2	27 13				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	3 2	13 23	19 10	30 7				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	1 0	7 8	19 22	26 5				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4		7 5	19 8					
V Cephei	23 51.7	+82 38	6.0— 7.0	0 23.9	3 2	10 2	17 1	24 1				

COMMUNICATIONS.

Determination of the Sizes of the Planetary Systems.—In a general way the planets of greatest mass and highest axial speed possess the most extensive satellite systems. This being the case, it should be possible to determine the size of a planetary system from certain elements of the planet's physical condition, such as its mass, density, axial velocity and the inclination of the planet's axis. The size of a system is found by adding the distances of the satellites from their primary, as Earth 238,800 miles and Jupiter 47,307,100 miles.

Placing M for the earth's factor and N for Jupiter's, we will have the proportion:

$$M : 238800 :: N : 47307100.$$

The factors M and N are composed of four factors each, the first of these is the planet's mass (a) and the second the planet's density (b). The third is the axial velocity (c) and the fourth the inclination of the planet's axis (d). The axial inclination of the earth is 23.5 degrees, or .87, that of Jupiter 3 degrees, or .98334, and that of Neptune 152 degrees or .155. The inclinations used are those from the North Poles of the planetary orbits. Perhaps one should use here the inclinations from the North Pole of the "Invariable Plane." However, there is very little difference between the two. The effect of factor (d) varies from 1.00 for a planet of zero inclination to zero for a planet inclined 180 degrees.

The four factors are used in the following manner:

$$a\,b\,c\,d : 238800 :: a'\,b'\,c'\,d' : 47307100.$$

Substituting the factors for the earth and Jupiter for $a\,b\,c\,d$ and $a'\,b'\,c'\,d'$ and replacing the moon's distance from the earth by x we have

$$1 \times 1 \times 1 \times .87 \; : \; x \; : : \; 317 \times .23 \times 2.42 \times .98334 \; : \; 47307100$$
$$47307100 \times .87 = 173.4426 \; x$$
$$x = 41157177 \div 173.4426$$
$$x = 237296$$

This gives 237296 miles for the moon's distance from the earth, being in error by .006.

In case one of the factors is unknown, it can of course be found by this method. In this way the axial period of Neptune (17 hours 8 minutes) and the distance of Saturn's satellites were determined.

	Axial Period Minutes	Inclination of Axis	Percent of Axial Inclination	Density	Mass	Distance of Satellites (miles)	Calculated Distances of Satellites	Percent of Error in Calculated Distances
Earth	1440	23.5	.87	1.00	1.00	238,800	237,296	.006
Mars	1477	23.5	.87	.73	1/9.32	20,500	18,122	.116
Jupiter	595	3.0	.98334	.23	317	47,307,100	47,307,100	none
Saturn	614	24.8	.851	.13	94.8	5,934,000*	6,708,323	.1155
Uranus	650	97.8	.456	.23	14.6	925,000	925,000	none
Neptune	1028	152	.155	.22	17.0	221,500	221,500	none

*Phoebe (distant 8,000,000 miles) evidently does not belong to the system, being an asteroid.

The accompanying table of data shows that the Earth, Jupiter and Uranus are in complete agreement with the formula, and that Neptune would be also if the computed axial period for that planet (17 hours 8 minutes) could be verified. The calculated satellite distances for Mars and Saturn have an error of about .115. The satellite Phoebe (distant 8,000,000 miles) belonging to the planet Saturn, has not been included in the sum of the distances of the satellites for that planet. To do so would make the satellite's distance altogether too large. The writer is inclined to think that the factor for the planet's axial period (c) should not be directly as the angular velocity, but as the square of that velocity. The size of the satellite systems in miles would then be Earth 238800, Mars 17800, Jupiter $2.42 \times 47{,}307{,}100$ or 114,483,182, Saturn 15,747,000 or 1,800,000 more than the observed distance of 13,934,000 (including Phoebe 8,000,000), Uranus 2,051,000 and Neptune 309,000.

If we use the square root of the density (b) instead of squaring the axial velocity, the distances in miles would be as follows: Earth 238,800, Mars 21,000, Jupiter 99,340,800, Saturn 18,696,000, Uranus 1,944,075 and Neptune 460,000. However the formula as first given seems to give the best results.

From the foregoing we find that the greater the mass, density and axial velocity of a planet, the greater the sum of the distances of its satellites. As the inclination of a planet's axis decreases (due to the effects of the solar tides) this also increases the satellites' distances.

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GENERAL NOTES

Latitude Variations. — In *Astronomische Nachrichten*, No. 5280, Dr. H. Wehner gives the results of an investigation of the various periods which are involved in the movement of the pole. It is customary to state that there are two principal terms, one of 12 months which depends upon meteorological conditions and one of 14 months which depends upon the rigidity of the earth. Dr. Wehner now finds that the principal period is one of 19 years, corresponding to the metonic cycle, with secondary periods corresponding to 16 sidereal months. He furthermore comes to the following conclusion: 1. It is not probable that the rotation axis will ever depart far from the axis of figure; 2. Seismic and volcanic disturbances, even the strongest, will have no effect on the periodic displacement of the pole; 3. Sudden displacements of the pole, should they ever occur, have nothing to do with the periodic displacement of the pole and would have to be attributed to tremendous effects within the earth's crust.

The Absolute Magnitudes of Long-Period Variable Stars.— A knowledge of the absolute magnitudes of the stars is of the greatest importance in any study of their evolution, and, in the case of variable stars, of a physical explanation of the cause of their variation. In *Contributions from the Mount Wilson Observatory*, No. 267, Merrill and Strömberg give the results of a study of the long-period variables of spectral class M. They reach the conclusion that the mean absolute magnitude (the apparent magnitude at a distance of 10 parsecs) of this class of stars is $+0.1$. By making some reasonable assumptions, the diameters of these stars appear to be from 100 to 200 times that of the sun and therefore they are stellar giants.

The Aurora Borealis. — The shimmering glow of the aurora borealis, which has mystified scientists for many years, is now declared to be due to the action of electric radiations on crystals of solid nitrogen floating in the upper atmosphere. The statement is made by the Norwegian scientist, Professor Lars Vegard of the University of Christiania, as the result of experiments made in the cryogenic laboratory of Dr. Kamerlingh Onnes at Leyden.

Earlier theories about the aurora attributed it to electric radiations from the sun. Professor Vegard extended these theories and concluded that the aurora was due to the action of these radiations on nitrogen "snow" which he assumed to exist at an altitude of more than sixty miles above the earth.

To test the theory he froze nitrogen on to a copper plate by chilling the plate to the temperature of liquid hydrogen, much as the moisture of a warm room is frozen on to refrigeration pipes in cold-storage plants. The rest of the nitrogen was mostly exhausted, resulting in greatly reduced pressure above the deposit of solid nitrogen. These crystals were then bombarded by cathode rays.

Using potentials of from 250 to 750 volts, Vegard was able to make the nitrogen crystals emit light of a greenish color, which, when examined in the spectroscope, proved to be identical with the mysterious strong green line in the spectrum of the aurora that has always been a puzzle to investigators. Vegard also found that the crystalline nitrogen kept on emitting this greenish light several minutes after the bombardment of cathode rays had ceased.

He also explains the wonderful changes of color in the aurora, for he found that under the electric excitation the solid nitrogen partly evaporates and then

begins to emit light of the reddish color so characteristic of nitrogen gas. (*Science Service.*)

Note on Red Dwarf Star, C.P.D.— 49°11439.—Attention has been called to this star (H. A., **99**, remark for H. D. 204961) by Miss Cannon, who finds that the Class M0 spectrum shows the line 4227 strong, as is characteristic of dwarfs. An examination of star catalogues, supplemented by three positions communicated by Mr. H. Spencer Jones, director of the Royal Observatory, Cape of Good Hope, yields the following data:

G. Z. 21^{h}785	Epoch 1872.7	21^h 26^m 52^s.95	—49° 25′ 20″.3
C. G. A. 29493	1880.7	.97	27.6
Cape	1893.5	.90	39.2
Cape	1904.6	.90	46.1
Cape	1905.6	.84	47.1

An annual proper motion of about 0″.8 in declination is indicated. Together with the apparent magnitude, 8.6, and the spectral class, this suggests a parallax of the order of 0″.1. (W. J. L.)

Harvard College Observatory Bulletin 801.
Cambridge, Massachusetts, April 1, 1924.

Ten New Variable Stars near Globular Clusters.— Near the cluster N. G. C. 5286, a long-period variable (H. V. 3722) has been found for which the position for 1900 is 13^h 45^m 32^s, —51° 52′.9. The approximate photographic magnitudes at maximum and minimum are 13 and 17. A maximum occurred in 1922, about J. D. 2423163, and a minimum in 1923, but the period cannot be determined from the eleven Bruce plates now available. No variables were found in the cluster.

The nine variable stars described below were found by a comparison of five photographs of the region within about a degree and a half of the globular cluster N. G. C. 6584. Four of these photographs were made in 1922, and one in 1923. For the study of the variables only three additional Bruce plates were available, one made in 1898, one in 1899, and one in 1904, two of which were badly broken in shipment. Five plates of the central part of this region were made in 1907 and 1908 with the 13-inch Boyden telescope, on which six of the variables are present, when they are near maximum. In general, the available data are insufficient for the determination of the periods. They are given, however, in a few cases, but should be regarded as provisional and somewhat doubtful. The positions are for 1900. All these variables are found in the southern half of the region examined. They furnish another example of the clustering tendency of such stars, noted in Harvard Bulletin 799. Five of them are situated within a circle whose radius is about 5′.

H. V. 3723. 18^h 1^m 45^s, —52° 25′.5. Maximum 12.0, Minimum [16.0.
Maximum = J. D. 2423621 + 247^d.0 E

H. V. 3724. 18^h 3^m 42^s, —52° 28′.7. Maximum 13.0, Minimum 14.5.
Period short, probably a few days, or less.

H. V. 3725. 18^h 8^m 57^s, —53° 35′.4. Maximum 13.5, Minimum 15.0.
Period short, a few days, or less.

H. V. 3726. 18^h 12^m 9^s, —52° 36′.1. Maximum 14.0, Minimum 15.0.
Period short, a few days, or less.

H. V. 3727. 18^h 12^m 27^s, —52° 41′.0. Maximum 12.0, Minimum 16.0.
Maximum = J. D. 2423624 + 238^d.4 E

H. V. 3728. $18^h\ 12^m\ 46^s$, $-52°\ 35'.4$. Maximum 13.0, Minimum 14.0. Period short, a few days, or less.

H. V. 3729. $18^h\ 12^m\ 52^s$, $-52°\ 36'.4$. Maximum 14.5, Minimum 16.0. Period short, a few days, or less.

H. V. 3730. $18^h\ 13^m\ 3^s$, $-52°\ 32'.0$. Maximum 13.0, Minimum 16.0. Maximum = J. D. 2423619 + $112^d.2$ E

H. V. 3731. $18^h\ 13^m\ 51^s$, $-52°\ 51'.1$. Maximum 10.5, Minimum 16.0. Maximum = J. D. 2417800 + 361^d E

(S. I. B.)

Harvard College Observatory Bulletin 801.

Dwarf Star of Small Proper Motion. — The star 16 c Ursae Majoris was found at Victoria to be a spectroscopic binary of low luminosity, and an orbit was published by Young (Publ. Dom. Astroph. Obs., **2**, No. 11, 1923). The position, visual magnitude, and spectrum are: $9^h\ 6^m.4$, $+61°\ 50'$, 5.2, and F8.

An interesting feature of this otherwise normal F8 dwarf is its extremely small proper motion, $0''.032$ annually. The available spectrum plates at Harvard place the absolute magnitude a little lower than +4. This would result in a parallax of $0''.06$, and accordingly a linear tangential velocity of two kilometers a second. The radial velocity of the center of gravity of the system is —15.0 kilometers.

It seems, therefore, that in about a million years this star may pass the sun at a distance of only two parsecs, at which time it will be of the first magnitude and located some ten degrees south of where α Hydrae is now.

Barnard's star and α Centauri are the only stars now known to be closer than two parsecs; they will pass the sun at distances of 1.1 and 0.93 parsecs, respectively. These distances we may compare with other close approaches in the past or future, such as those of Kapteyn's star, 1.6 parsecs ten thousand years ago, and of 279 Sagittarii, 1.4 parsecs thirty-five thousand years hence.

(W. J. L.)

Harvard College Observatory Bulletin 802.

The Royal Photographic Society of Great Britain is holding its sixty-ninth annual exhibition in September and October of this year. This is the most representative exhibition of photographic work in the world, and the section sent by American scientific men heretofore has sufficiently demonstrated the place held by this country in applied photography. It is very desirable that American scientific photography should be equally well represented in 1924, and, in order to enable this to be done with as little difficulty as possible, Mr. A. J. Newton, of the Eastman Kodak Company, Rochester, N. Y., has arranged to collect and forward American work intended for the Scientific section.

This work should consist of prints showing the use of photography for scientific purposes and its application to spectroscopy, astronomy, radiography, biology, etc. Photographs should reach Mr. Newton not later than Saturday, June 14. They should be mounted but not framed. There are no fees.

Mr. Newton would be glad if any worker who is able to send photographs will communicate with him as soon as possible so that he may arrange for the receiving and entry of the exhibit.

Erratum. — In Plate IX, April 1924 number of POPULAR ASTRONOMY, Fig. 5 should be inverted.